Land Ownership and Irrigation on American Indian Reservations: A Regression Discontinuity Approach

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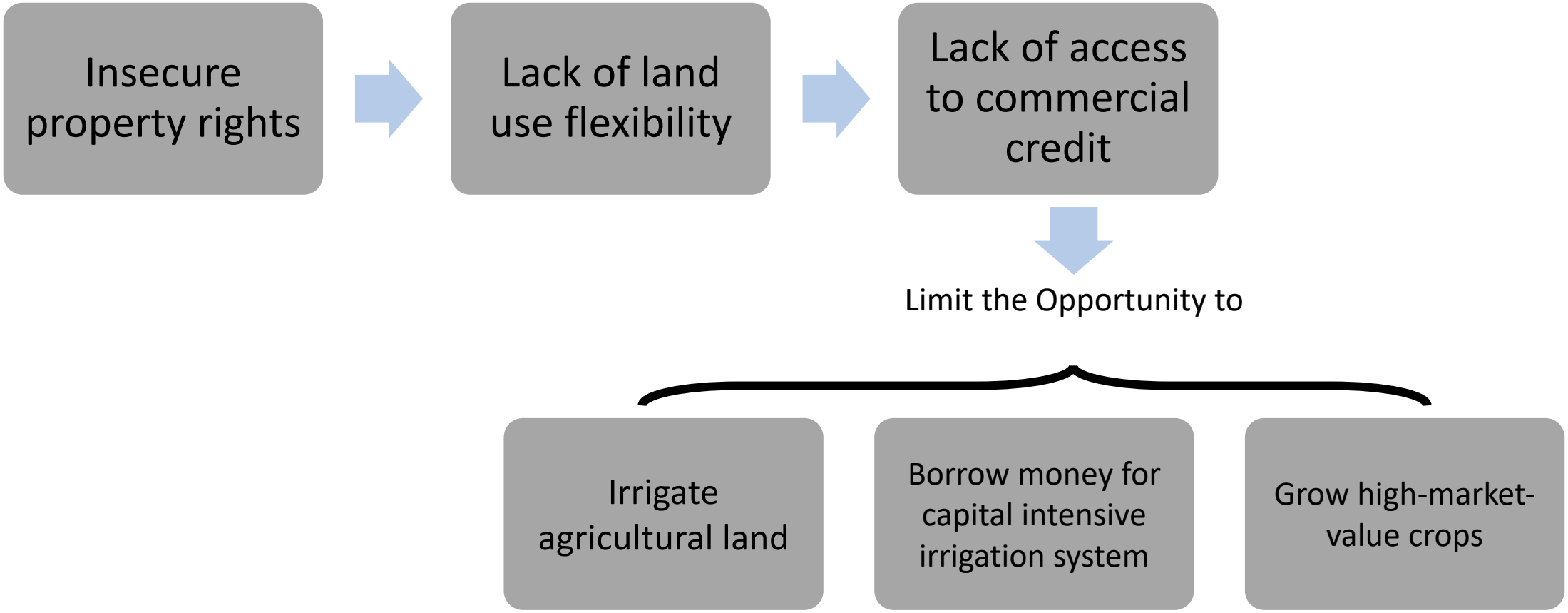
Property Rights and Agricultural Investment

- Individuals do not invest if the fruits of their investments are seized by others. (Demsetz, 1967; Alchian and Demsetz, 1973)
- If better rights make it easier to use land as collateral, then constrains on funding investments can be diminished. (Feder et al; 1988)
- Investment is encouraged if improved transfer rights make it easier for individuals to rent or sell their land. (Besley, 1995)

Research Questions

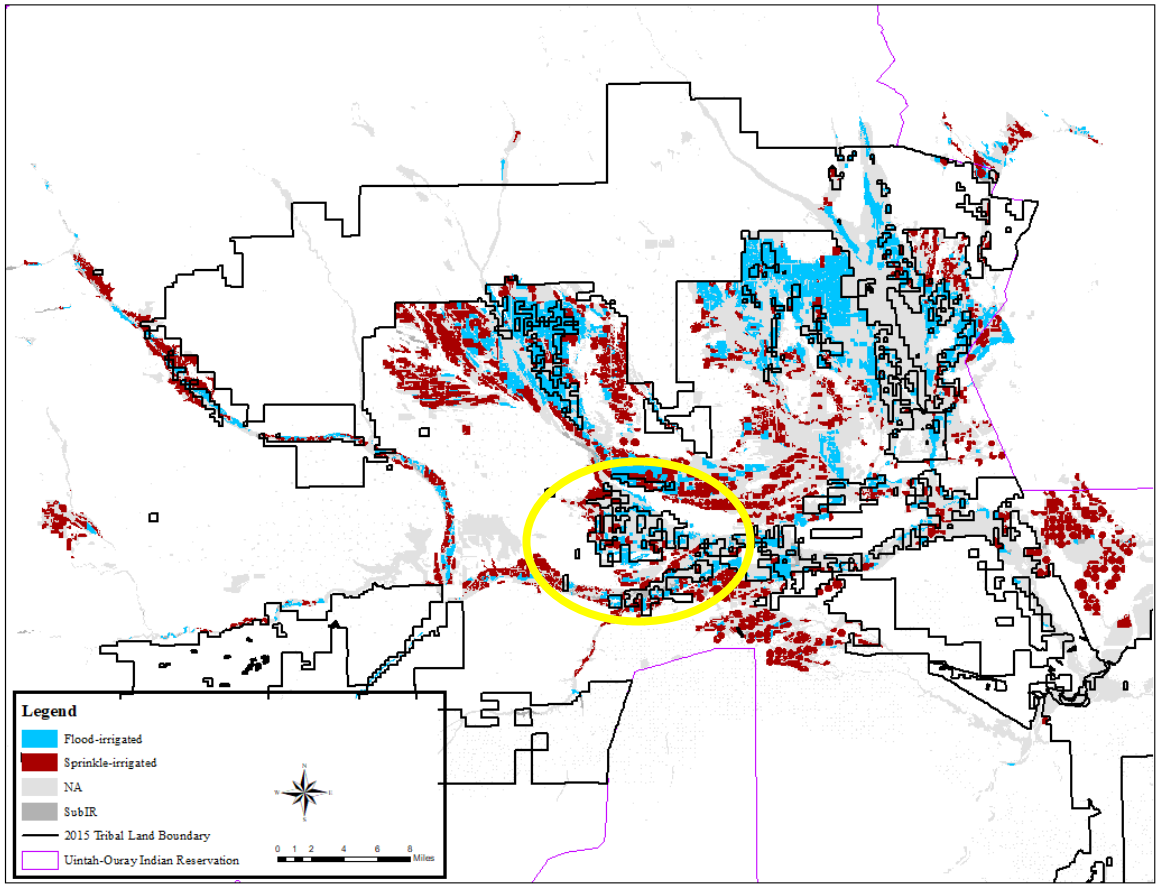


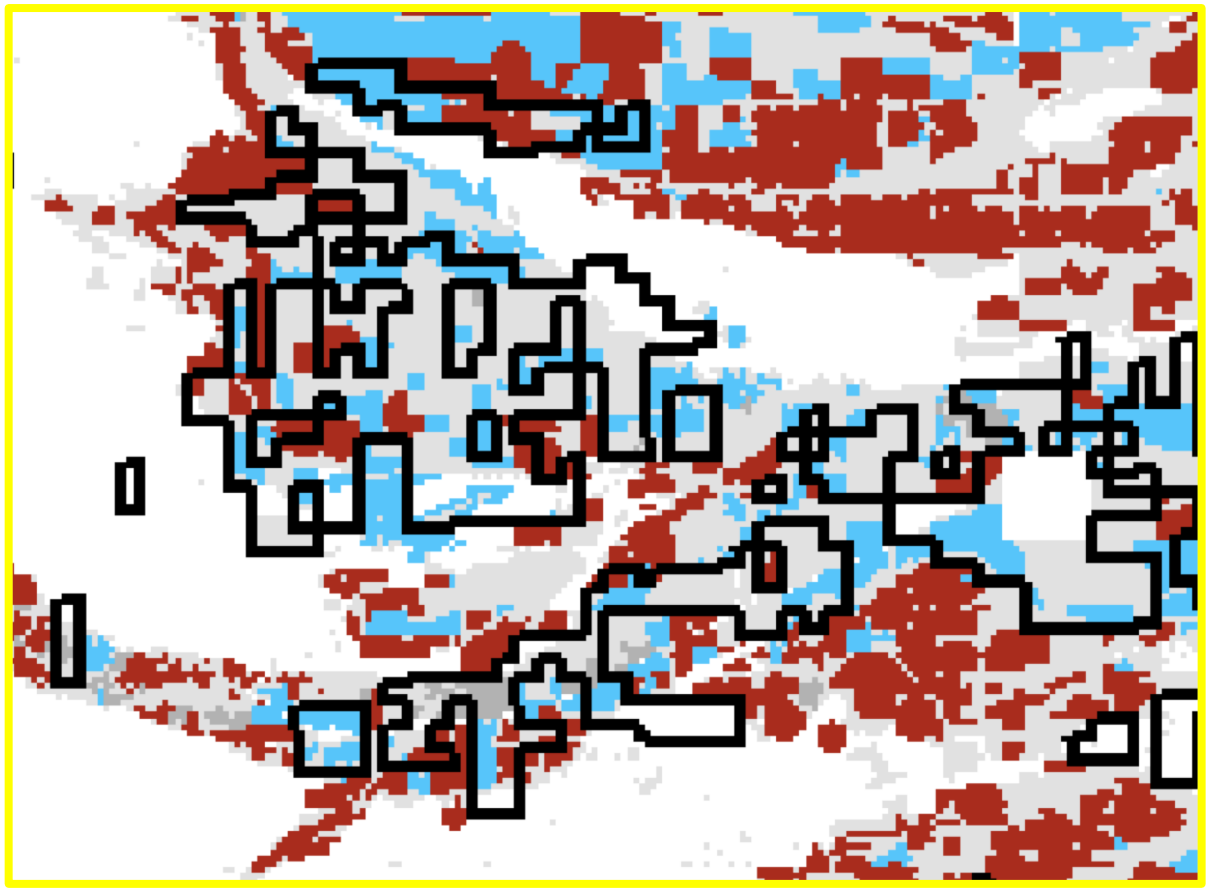
Land Tenure and Indian Reservations

- Lack of economic development on reservations
- Insecure property rights
  - Tribal Trust land held in trust for tribes by federal government
  - Managed by tribe and Bureau of Indian Affairs
- Insecure property rights may explain lack of development
- Can we observe this in the investment in capital-intensive agricultural development?

Irrigation on the Uintah Reservation

Table 1-2 2015 Irrigation Map





Summary of Results

- When controlling for land quality and geographic location:
  - Private land is approximately 7 percentage point more irrigated than tribal land in 2015.
  - Of all the irrigated land, tribal land is 30 percentage point less likely to be sprinkle-irrigated today.
  - Today, private owners occupied 2 percentage point more high-value crops within 5 miles of 2015 Tribal Boundary.
- Only regressing the “no ownership change land”:
  - Private land is still around 6 percentage point more irrigated than tribal land in 2015.
  - Of all the irrigated land, tribal land is 20 percentage point less likely to be sprinkle-irrigated today.

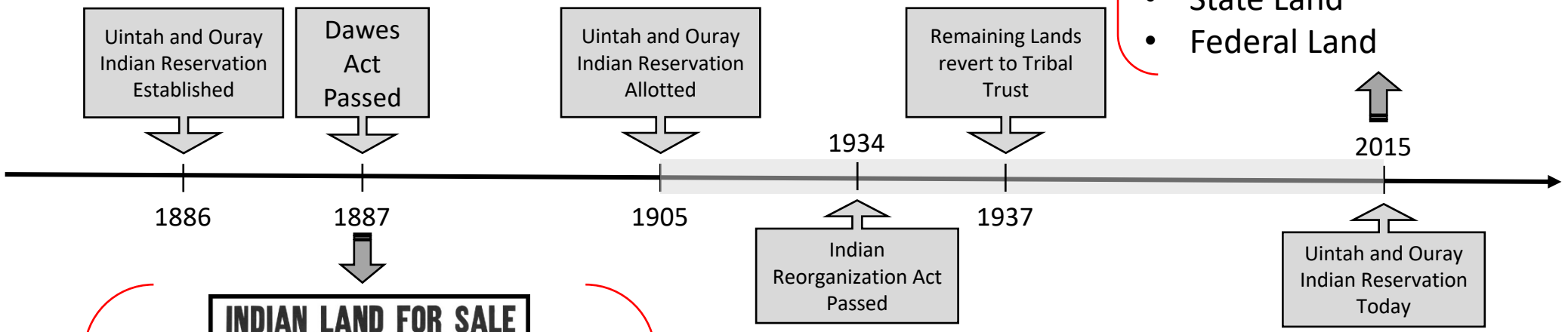
Outline

- Uintah land history
- Literature
- Predictions
- Data
  - Data description
  - Unit of observation construction
- Methodology
  - 1905 sharp RD design
  - 2015 fuzzy RD design
- Results
- Conclusion

Uintah Land History

Four Different Land Ownerships:

- Tribal Land
- Private Land
- State Land
- Federal Land



Started the process by which significant portions of the reservation were reallocated to private individuals

DEPARTMENT OF THE INTERIOR
GENERAL LAND OFFICE
WILLIAM SPRY, COMMISSIONER

PART OF

UINTA INDIAN RESERVATION
UTAH

To be disposed of
under
ACT OF MARCH 3, 1905
and
PRESIDENT'S PROCLAMATION
dated July 14, 1906

GRAZING LAND

GRAZING LAND

GRAZING LAND

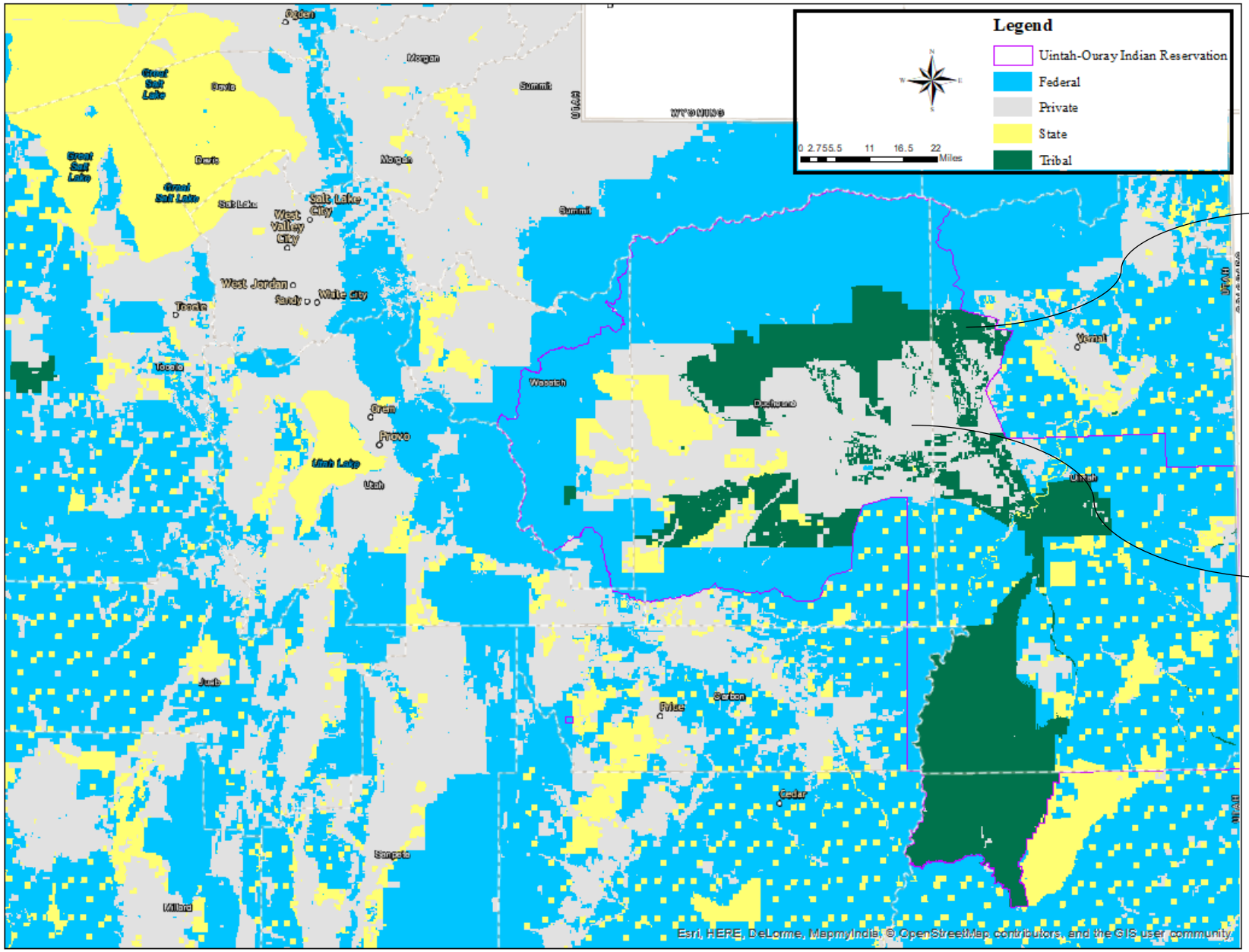
NOTE

Land reserved for Townsite by
later Proclamation of President

S½ SW¼ Sec. 13, NW¼ Sec. 20, N½ Sec. 30, T. 3 S., R. 1 W., and
Lots 3, 5 and 6 Sec. 25 and Lot 1 Sec. 26 T. 3 S., R. 2 W.

LEGEND

- Forest Reservation
- Grazing Land
- Irrigated and/or Timber Rec.
- Military Reserve
- Townsite
- Allotments
- Reserved for Irrigation—Indian
- Reserved for Agency, Schools and other purposes
- Reserved for Irrigation—U.S.G.S.
- Mines or Claims



- Tribal land use is under approval of Bureau of Indian Affairs (BIA).
- Agricultural lease: up to 10 years.
- The land is not leased for agricultural purpose: up to 5 years.

- The owner of the private land has the complete property rights and can freely sell or lease the land.

Literature

- The link between insecure property rights and poverty on American Indian reservations has drawn significant attention in recent years.
  - Trust land constraints imposed by the federal government significantly reduced the value of agricultural output on reservation land. (Anderson and Lueck, 1992)
  - Better land rights lower foreclosure costs, and lead to expanded trading opportunities and the ability to exploited gains from trade, enhance investment incentives. (Besley, 1995)
  - Reservations that adopt stronger governmental institutions were able to accelerate employment and income growth. (Cornell and Kalt, 2000)
  - Anderson and Parker (2008) show that a law that allow tribes to make credible commitments to outsiders on adherence to contract agreements increased economic growth

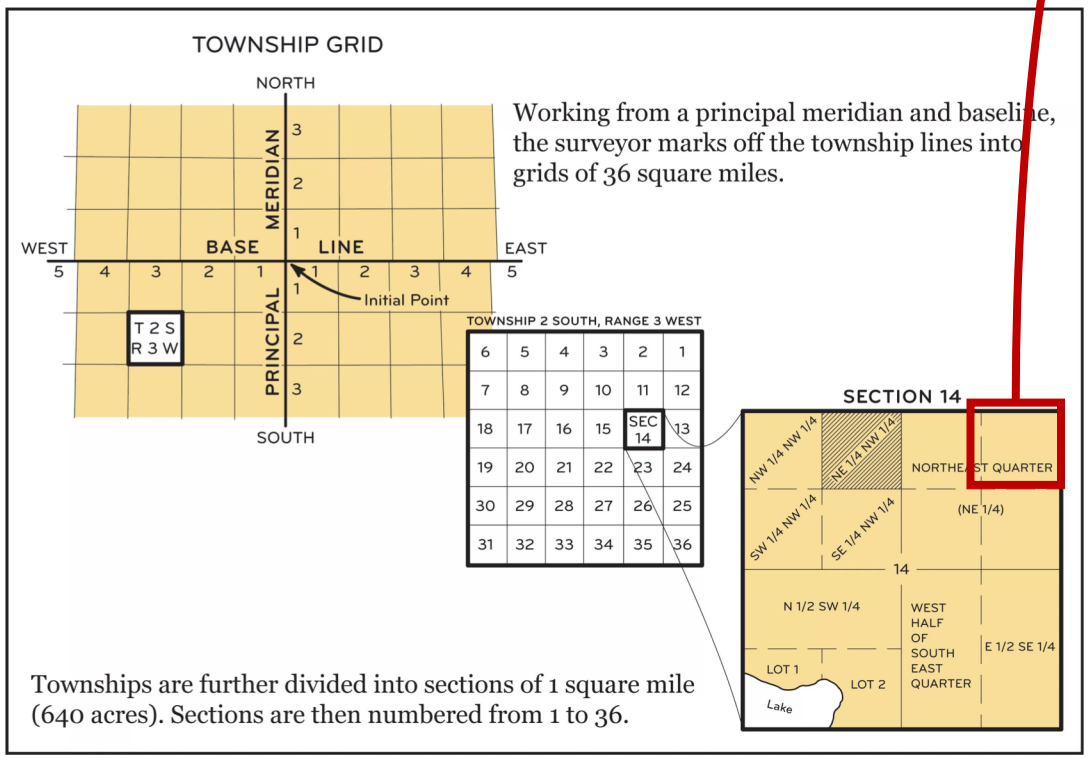
Predictions

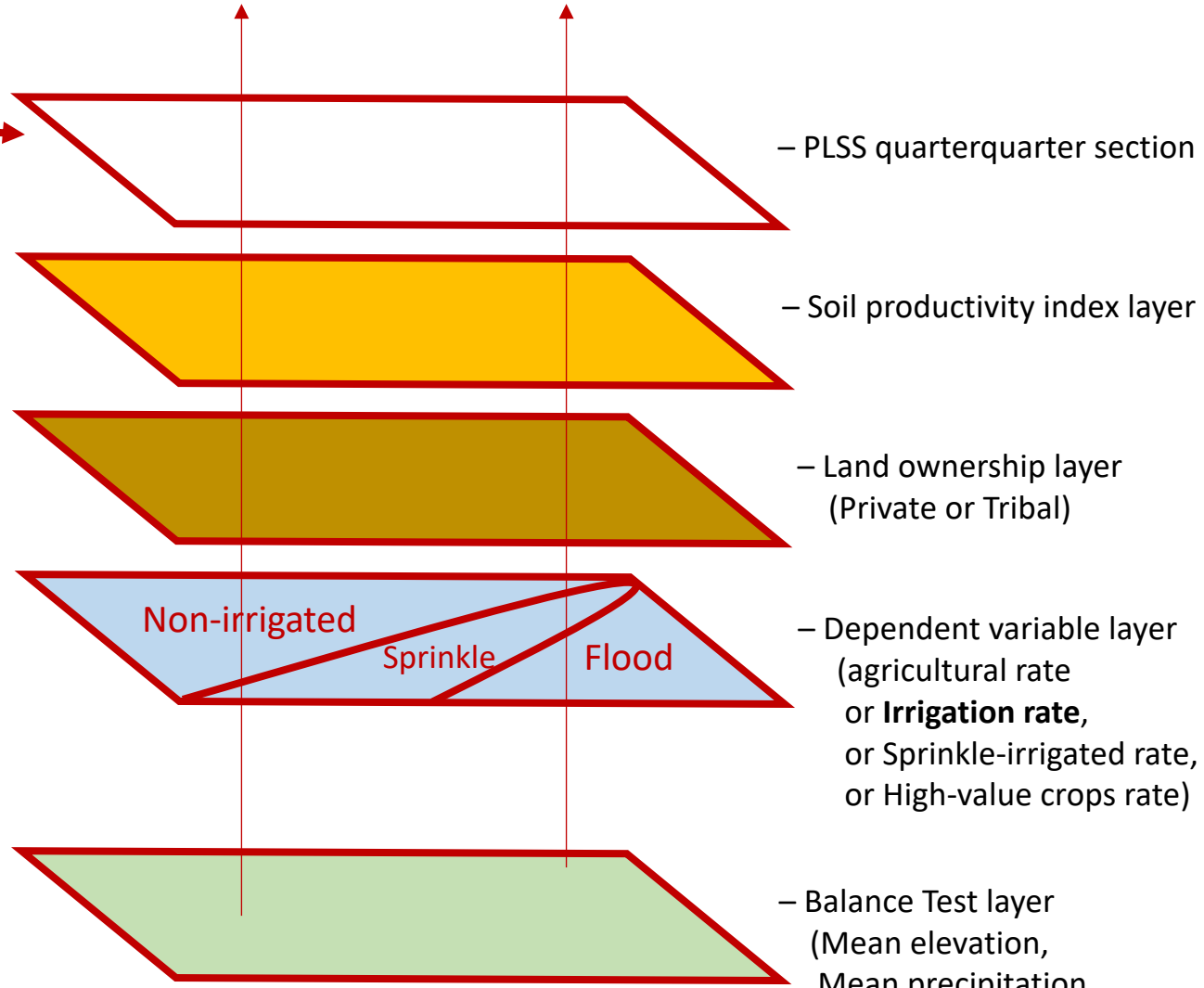
- Irrigation Rate: Higher on private land
- Sprinkle-irrigated Rate: Higher on private land
- High-market-value crops Rate: Higher on private land

Data

- Dependent variables:
  - **Soil productivity**: Soil productivity index grid (Schaetzl et al., 2012)
  - **Agricultural rate**: CropScape-Cropland Data Layer (Year 2015)
  - **Irrigation rate**: Water Related Land Use (Utah Division of Water Resources)
  - **Sprinkle-irrigated rate**: Water Related Land Use (Utah Division of Water Resources)
  - **High-value cropland rate**: Water Related Land Use (Utah Division of Water Resources)
- Running variable:
  - **Distance** to each boundary: GIS calculation
- Treatment variables:
  - **2015 Land ownership**: State Geographic Information Database
  - **1905 Land ownership**: Uintah Indian Reservation Disposition map, 1905

Unit of observations: **Utah Public land survey system (PLSS) quarter, quarter sections** of 40 acres





– PLSS quarterquarter section

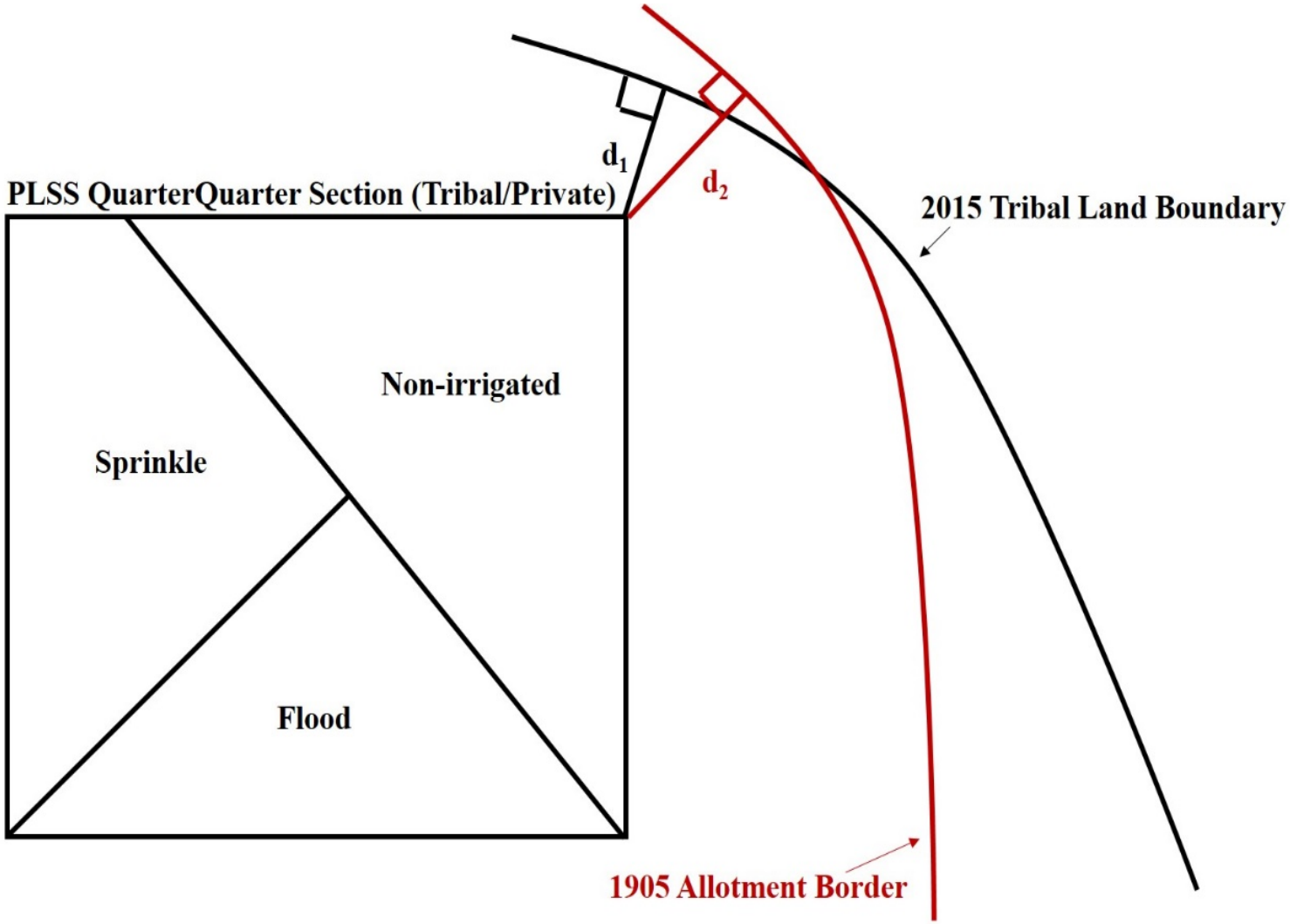
– Soil productivity index layer

– Land ownership layer
(Private or Tribal)

– Dependent variable layer
(agricultural rate
or **Irrigation rate**,
or Sprinkle-irrigated rate,
or High-value crops rate)

– Balance Test layer
(Mean elevation,
Mean precipitation,
Mean temperature)

Distance calculation



Methodology

A. Empirical framework of 1905 Allotment Border

$$Allotment1905_i = \begin{cases} 1 & if \quad dist1905_i \geq \overline{dist} = 0 \\ 0 & if \quad dist1905_i < \overline{dist} = 0 \end{cases}$$

Linear (parametric) RD using all observations (Dell, 2010):

$$R1905_i = \alpha + \beta_1 Allotment1905_i + \beta_2 (dist1905_i - \overline{dist}) + \beta_3 \left(dist1905_i - \overline{dist}\right) \times Allotment1905_i + \varepsilon_i$$

Methodology

- Sharp Regression Discontinuity Approach

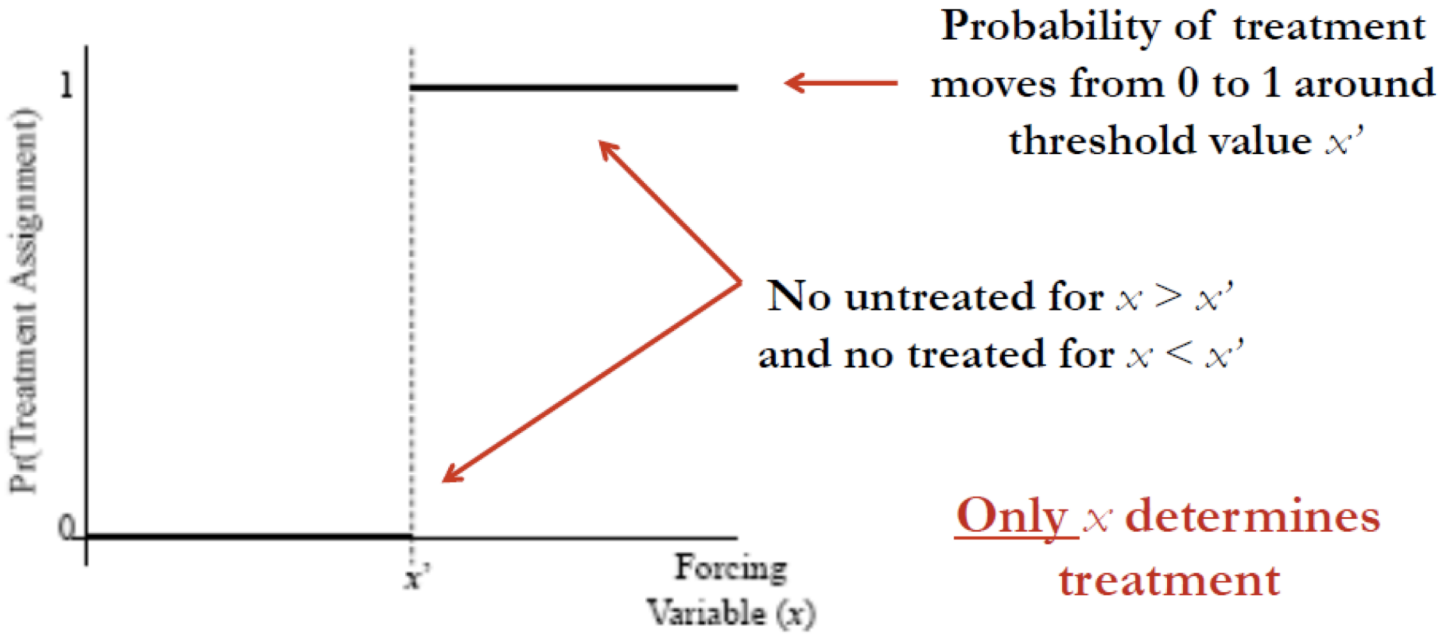


Figure is from Roberts and Whited (2010)

Methodology

B. Empirical framework of 2015 Tribal Land Boundary

$$Uintah2015_i = \begin{cases} 1 & if \quad dist2015_i \geq \overline{dist} = 0 \\ 0 & if \quad dist2015_i < \overline{dist} = 0 \end{cases}$$

The instrumental variable $Allotment1905$ is defined as

$$Allotment1905_i = Allotment(dist2015_i) = 1\left(dist2015_i \geq \overline{dist}\right) \equiv \begin{cases} 1 & if \quad dist2015_i \geq \overline{dist} = 0 \\ 0 & if \quad dist2015_i < \overline{dist} = 0 \end{cases}$$

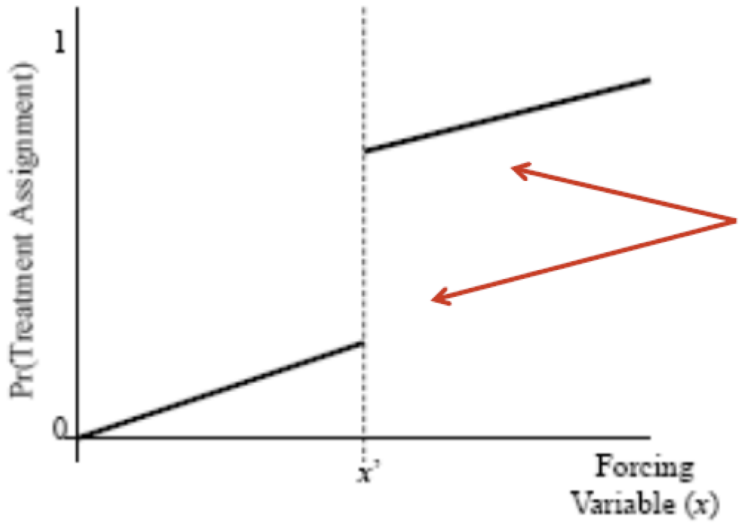
linear (Parametric) RD model (2SLS) using all observation:

Stage 1: $Uintah2015_i = \lambda + \gamma Allotment1905_i + g_{Uintah2015_i}(dist1905_i - \overline{dist}) + \nu_i$

Stage 2: $R2015_i = \delta + \beta_1 \widehat{Uintah2015}_i + g_{Uintah2015_i}(dist1905_i - \overline{dist}) + \varepsilon_i$

Methodology

- Fuzzy Regression Discontinuity Approach



Treatment probability increases at x'

Some untreated for $x > x'$ and some treated for $x < x'$

Treatment is not purely driven by x

Figure is from Roberts and Whited (2010)

Balance Test

Table 1 Balance test Statistics

	< 1 Miles		*< 2 Miles*		*< 3 Miles*		*< 4 Miles*		*< 5 Miles*	
	outside	inside	outside	inside	outside	inside	outside	inside	outside	inside
1905 Allotment Border										
					Climate Statistics					
Observations	1,954	1,368	3,212	1,802	4,398	2,018	5,374	2,108	6,242	2,127
Annual Mean Temperature (°C)	6.42	6.33	6.29	6.03	6.13	5.91	6.02	5.83	5.91	5.80
	(1.65)	*(1.44)*	*(1.81)*	*(1.47)*	*(2.01)*	*(1.47)*	*(2.13)*	*(1.52)*	*(2.25)*	*(1.55)*
Max Temperature of Warmest Month(°C)	29.46	29.20	29.26	28.64	29.00	28.41	28.84	28.27	28.68	28.22
	(2.99)	*(2.69)*	*(3.22)*	*(2.68)*	*(3.50)*	*(2.66)*	*(3.68)*	*(2.71)*	*(3.85)*	*(2.75)*
Min Temperature of Coldest Month(°C)	-14.78	-14.58	-14.79	-14.42	-14.79	-14.36	-14.78	-14.35	-14.78	-14.35
	(0.85)	*(0.89)*	*(0.85)*	*(0.85)*	*(0.85)*	*(0.82)*	*(0.86)*	*(0.81)*	*(0.86)*	*(0.80)*
Annual Precipitation(mm)	262.28	260.57	270.28	274.90	281.36	280.91	288.56	285.50	295.85	287.32
	(90.27)	*(75.33)*	*(99.60)*	*(78.52)*	*(112.40)*	*(79.54)*	*(119.00)*	*(82.80)*	*(124.84)*	*(84.82)*
Precipitation of Driest Month(mm)	16.12	16.02	16.67	17.25	17.39	17.74	17.88	18.08	18.37	18.20
	(7.49)	*(6.72)*	*(7.90)*	*(6.91)*	*(8.46)*	*(6.94)*	*(8.78)*	*(7.10)*	*(9.11)*	*(7.19)*
					Land Statistics					
Observations	8,833	5,992	14,505	7,822	19,479	8,755	23,784	9,161	27,583	9,227
Elevation(m)	1,876.35	1,926.54	1,909.89	1,991.70	1,939.50	2,021.76	1,965.14	2,040.91	1,987.33	2,045.91
	(352.34)	*(336.40)*	*(390.25)*	*(333.09)*	*(423.39)*	*(331.99)*	*(448.97)*	*(340.16)*	*(471.66)*	*(344.26)*
Soil Productivity	6.96	6.95	6.91	6.76	6.99	6.70	7.02	6.70	7.04	6.70
	(2.93)	*(2.18)*	*(3.16)*	*(1.96)*	*(3.37)*	*(1.86)*	*(3.48)*	*(1.82)*	*(3.54)*	*(1.82)*

2015 Tribal Boundary

					Climate Statistics					
Observations	4,395	3,215	7,388	4,238	10,059	4,861	12,403	5,232	14,402	5,479
Annual Mean Temperature (°C)	6.81	6.54	6.66	6.42	6.56	6.35	6.43	6.31	6.35	6.30
	(1.64)	*(1.68)*	*(1.77)*	*(1.71)*	*(1.87)*	*(1.70)*	*(2.00)*	*(1.68)*	*(2.10)*	*(1.66)*
Max Temperature of Warmest Month(°C)	29.96	29.45	29.70	29.19	29.52	29.02	29.32	28.91	29.18	28.86
	(2.98)	*(3.17)*	*(3.14)*	*(3.20)*	*(3.27)*	*(3.17)*	*(3.44)*	*(3.13)*	*(3.59)*	*(3.09)*
Min Temperature of Coldest Month(°C)	-14.50	-14.38	-14.43	-14.24	-14.38	-14.14	-14.36	-14.06	-14.34	-13.99
	(1.17)	*(1.21)*	*(1.18)*	*(1.23)*	*(1.19)*	*(1.23)*	*(1.21)*	*(1.24)*	*(1.23)*	*(1.25)*
Annual Precipitation(mm)	268.47	277.86	280.20	286.02	288.81	290.66	297.73	294.13	304.67	296.52
	(87.08)	*(86.87)*	*(93.28)*	*(87.34)*	*(98.38)*	*(86.34)*	*(104.95)*	*(85.87)*	*(110.83)*	*(85.41)*
Precipitation of Driest Month(mm)	16.12	16.95	16.95	17.58	17.52	17.95	18.08	18.18	18.45	18.32
	(6.70)	*(6.78)*	*(7.02)*	*(6.77)*	*(7.24)*	*(6.67)*	*(7.53)*	*(6.59)*	*(7.78)*	*(6.51)*
					Land Statistics					
Observations	19,811	14,233	32,782	18,698	44,273	21,381	54,379	22,995	63,562	24,086
Elevation(m)	1,876.19	1,926.65	1,911.74	1,969.17	1,938.42	1,996.70	1,964.93	2,013.31	1,988.31	2,023.72
	(352.68)	*(378.90)*	*(368.89)*	*(382.97)*	*(384.65)*	*(381.72)*	*(404.51)*	*(378.96)*	*(423.93)*	*(376.41)*
Soil Productivity	6.88	7.30	6.97	7.23	7.10	7.18	7.23	7.19	7.32	7.24
	(4.12)	*(4.24)*	*(4.24)*	*(4.27)*	*(4.33)*	*(4.27)*	*(4.41)*	*(4.34)*	*(4.45)*	*(4.42)*

Notes: The unit of observation is PLSS QuarterQuarter Section. Summary statistics table show two datasets: climate statistics dataset and land statistics dataset. The land statistics dataset contains all the private and tribal parcels of Uintah and Ouray Indian reservation, while the climate statistics dataset only contains most representative PLSS parcels.

1905 Allotment Border Results (RD)

Table 2 1905 Allotment Border Non-parametric RD Results (Second order polynomial)

Sample Within	Estimated Average Treatment Effects							Control Variables	
	<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth	Optimal Miles	Townships	Soil Productivity
Soil Productivity Index									
Allotment1905	0.1329**	0.0464	0.0144	0.0075	0.0130	0.1329	1.3465	√	
	(0.0725)	(0.0786)	(0.0876)	(0.1003)	(0.1141)	(0.0725)			
Agricultural Rate									
Allotment1905	0.0660***	0.0560***	0.0339**	0.0338**	0.0258	0.0269	1.1982	√	√
	(0.0116)	(0.0126)	(0.0143)	(0.0167)	(0.0197)	(0.0184)			
Irrigation Rate									
Allotment1905	0.0220	0.0168	0.0109	0.0140	0.0376	0.0371	1.0629	√	√
	(0.0149)	(0.0161)	(0.0179)	(0.0208)	(0.0245)	(0.0242)			
Sprinkle-irrigated Rate									
Allotment1905	-0.0867***	-0.0996***	-0.1253***	-0.1337***	-0.1310***	-0.1353***	1.2449	√	√
	(0.0158)	(0.0172)	(0.0194)	(0.0227)	(0.0271)	(0.0266)			
High-value Crops Rate									
Allotment1905	0.0053	0.0006	-0.0012	0.0009	-0.0065	-0.0049	1.2374	√	√
	(0.0046)	(0.0050)	(0.0055)	(0.0063)	(0.0074)	(0.0070)			

Notes: Coefficients significantly different from zero are denoted by the following system: * 10%, ** 5%, and *** 1%. Robust standard errors are provided in the parenthesis.

1905 Allotment Border Results (RD)

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	(0.0725)	(0.0786)	(0.0876)	(0.1003)	(0.1141)	(0.0725)			
Agricultural Rate									
Allotment1905	0.0660***	0.0560***	0.0339**	0.0338**	0.0258	0.0269	1.1982	√	√
	(0.0116)	(0.0126)	(0.0143)	(0.0167)	(0.0197)	(0.0184)			
Irrigation Rate									
Allotment1905	0.0220	0.0168	0.0109	0.0140	0.0376	0.0371	1.0629	√	√
	(0.0149)	(0.0161)	(0.0179)	(0.0208)	(0.0245)	(0.0242)			
Sprinkle-irrigated Rate									
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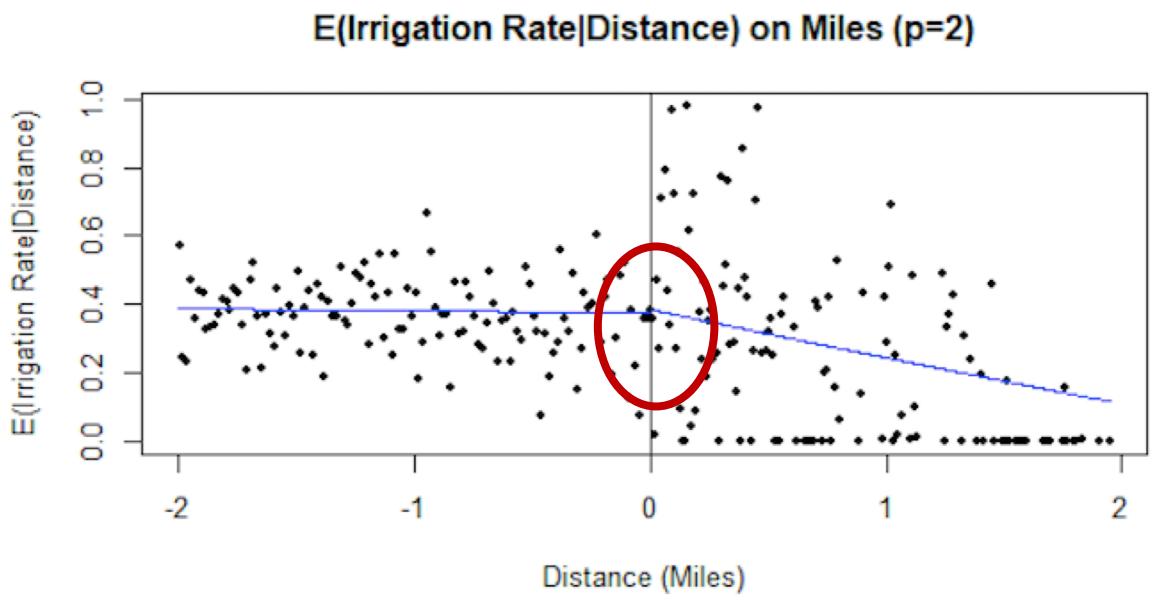
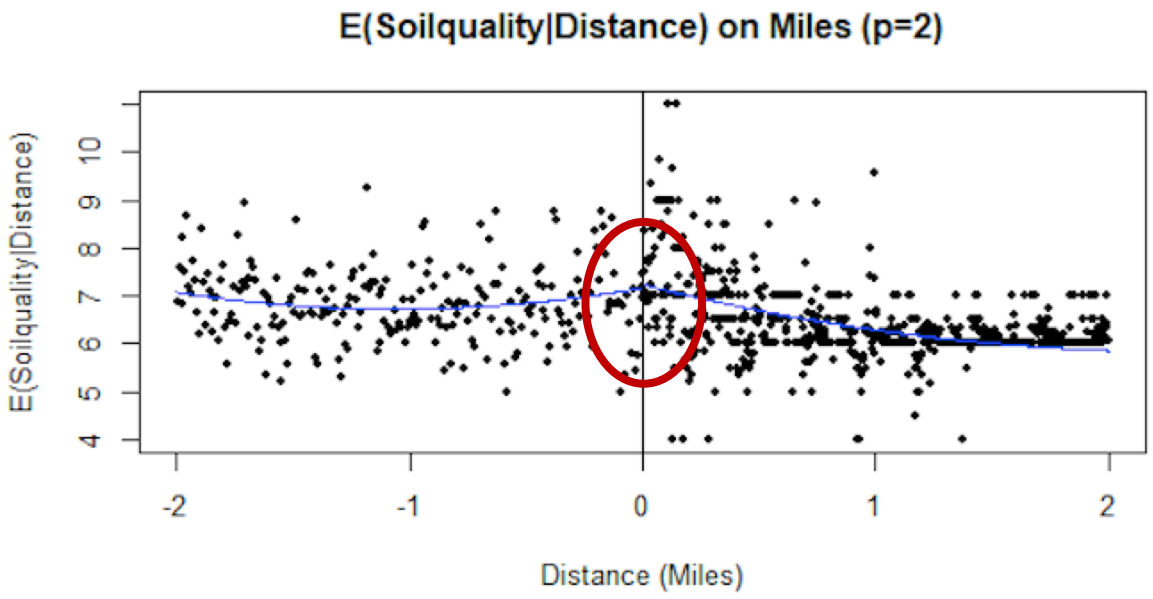
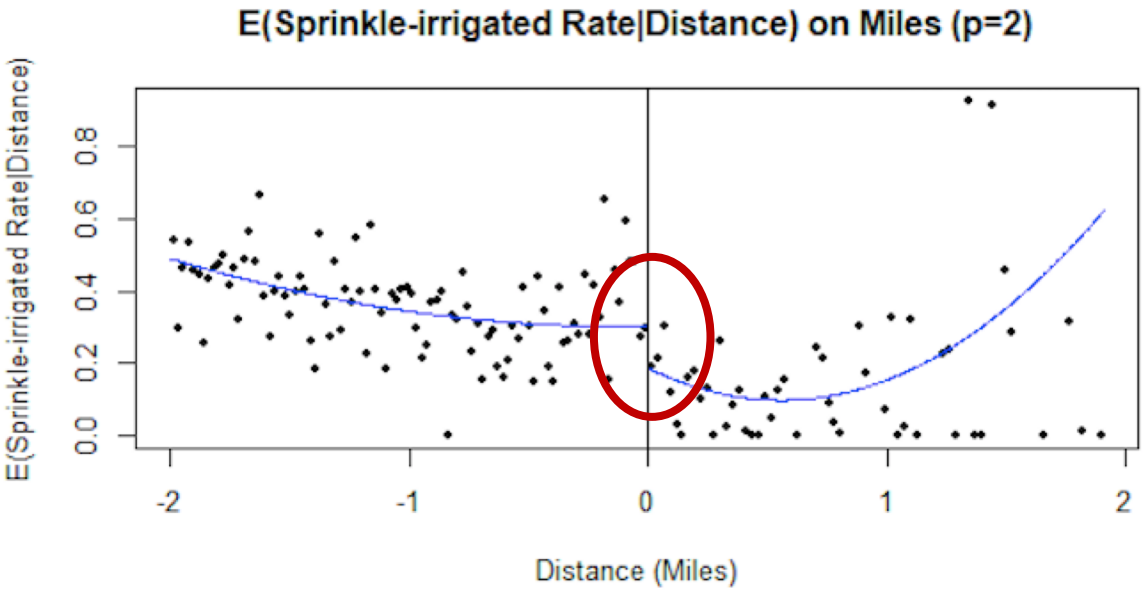
	(0.0158)	(0.0172)	(0.0194)	(0.0227)	(0.0271)	(0.0266)			
High-value Crops Rate									
Allotment1905	0.0053	0.0006	-0.0012	0.0009	-0.0065	-0.0049	1.2374	√	√
	(0.0046)	(0.0050)	(0.0055)	(0.0063)	(0.0074)	(0.0070)			

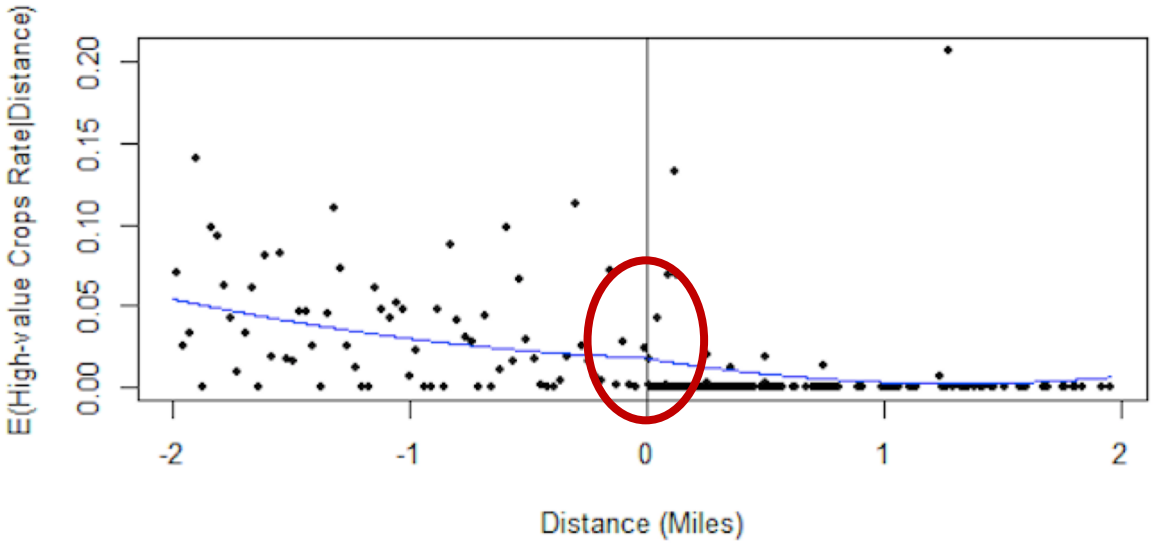
Notes: Coefficients significantly different from zero are denoted by the following system: * 10%, ** 5%, and *** 1%. Robust standard errors are provided in the parenthesis.

~-12 percentage points


E(Irrigation Rate|Distance) on Miles (p=2)
E(Irrigation Rate|Distance)
0.0
0.2
0.4
0.6
0.8
1.0
-2
-1
0
1
2
Distance (Miles)


E(Soilquality|Distance) on Miles (p=2)
E(Soilquality|Distance)
4
5
6
7
8
9
10
-2
-1
0
1
2
Distance (Miles)


E(Sprinkle-irrigated Rate|Distance) on Miles (p=2)
E(Sprinkle-irrigated Rate|Distance)
0.0
0.2
0.4
0.6
0.8
-2
-1
0
1
2
Distance (Miles)


E(High-value Crops Rate|Distance) on Miles (p=2)
E(High-value Crops Rate|Distance)
0.00
0.05
0.10
0.15
0.20
-2
-1
0
1
2
Distance (Miles)

2015 Tribal Land Boundary Results (Fuzzy RD)

Table 3 2015 Tribal Boundary Non-parametric RD Results (Second order polynomial)

Sample Within	Estimated Average Treatment Effects							Control Variables	
	<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth	Optimal Miles	Townships	Soil Productivity
Soil Productivity Index									
Tribal2015	1.0564***	1.2737***	1.4662***	1.7824***	2.0620***	1.4809***	2.0245	√	
	(0.3066)	(0.3196)	(0.3433)	(0.3980)	(0.4692)	(0.3678)			
Agricultural Rate									
Tribal2015	0.0822***	0.0672***	0.0451*	0.0001	-0.0040	-0.0044	1.2222	√	√
	(0.0227)	(0.0245)	(0.0268)	(0.0309)	(0.0373)	(0.0365)			
Irrigation Rate									
Tribal2015	-0.0707***	-0.0793***	-0.0744***	-0.0701***	-0.0668***	-0.0666***	0.8723	√	√
	(0.0110)	(0.0115)	(0.0120)	(0.0128)	(0.0135)	(0.0135)			
Sprinkle-irrigated Rate									
Tribal2015	-0.2648***	-0.2797***	-0.2855***	-0.3068***	-0.3094***	-0.3205***	1.4005	√	√
	(0.0277)	(0.0301)	(0.0333)	(0.0388)	(0.0458)	(0.0429)			
High-value Crops Rate									
Tribal2015	-0.0173**	-0.0151*	-0.0130	-0.0218*	-0.0387***	-0.0329**	1.1307	√	√
	(0.0082)	(0.0089)	(0.0100)	(0.0116)	(0.0135)	(0.0131)			

Notes: Coefficients significantly different from zero are denoted by the following system: * 10%, ** 5%, and *** 1%. Robust standard errors are provided in the parenthesis.

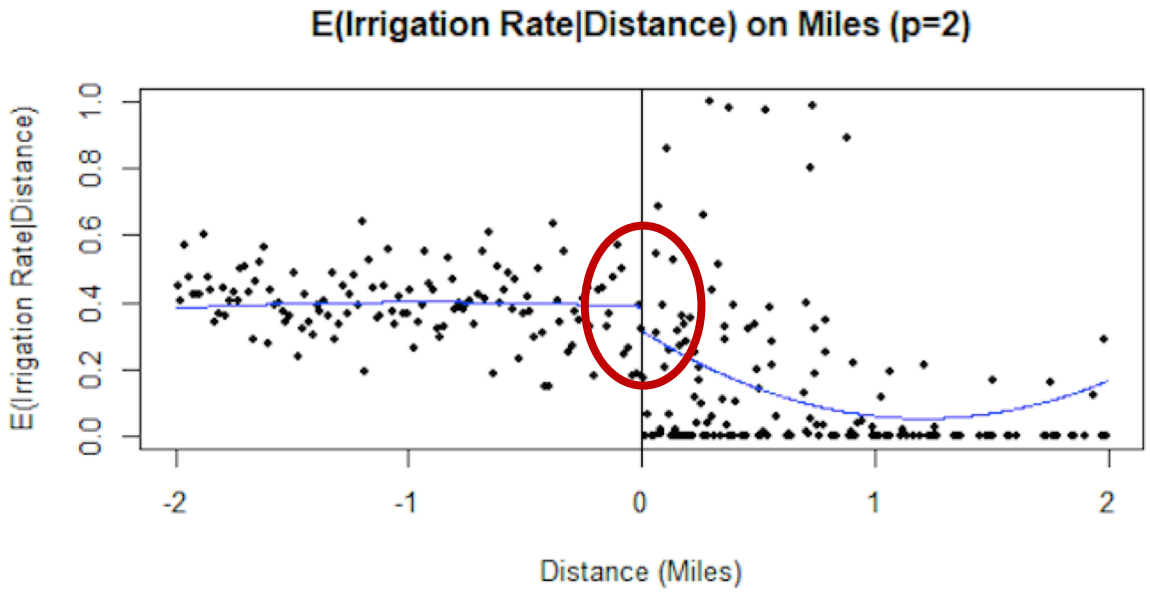
2015 Tribal Land Boundary Results (Fuzzy RD)

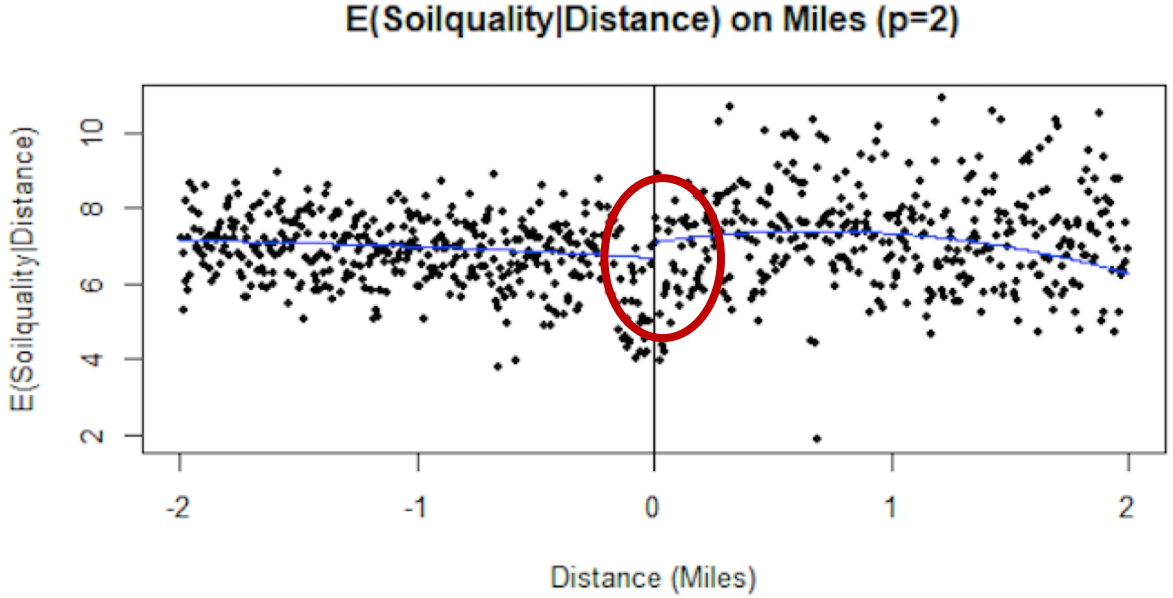
Table 3 2015 Tribal Boundary Non-parametric RD Results (Second order polynomial)

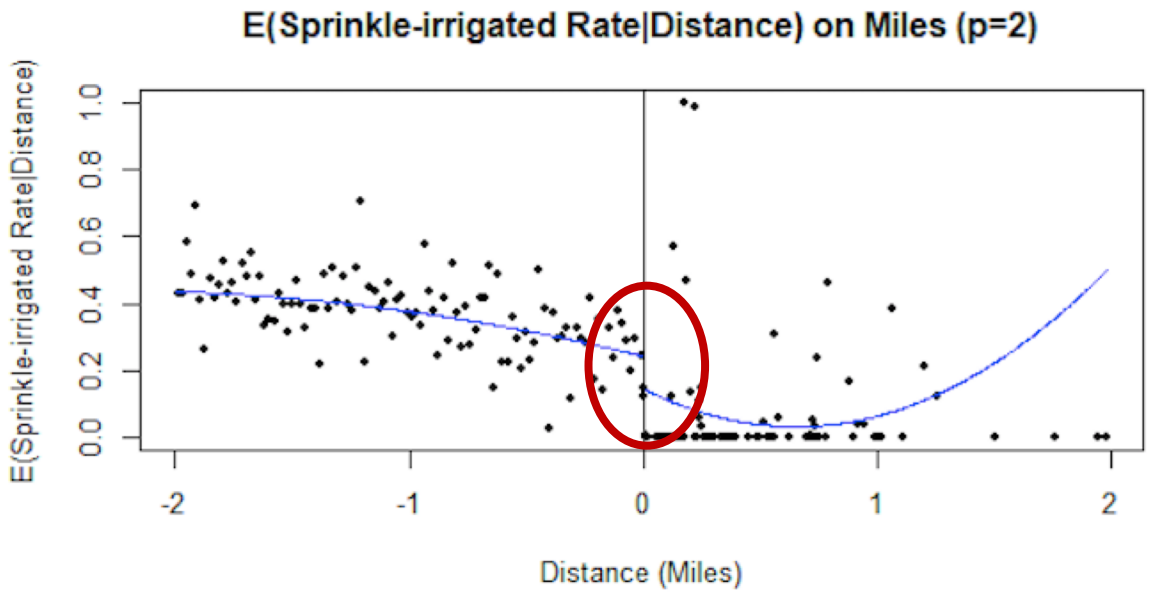
Sample Within	Estimated Average Treatment Effects							Control Variables	
	<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth	Optimal Miles	Townships	Soil Productivity
Soil Productivity Index									
Tribal2015	1.0564***	1.2737***	1.4662***	1.7824***	2.0620***	1.4809***	2.0245	√	
	(0.3066)	(0.3196)	(0.3433)	(0.3980)	(0.4692)	(0.3678)			
Agricultural Rate									
Tribal2015	0.0822***	0.0672***	0.0451*	0.0001	-0.0040	-0.0044	1.2222	√	√
	(0.0227)	(0.0245)	(0.0268)	(0.0309)	(0.0373)	(0.0365)			
Irrigation Rate									
Tribal2015	-0.0707***	-0.0793***	-0.0744***	-0.0701***	-0.0668***	-0.0666***	0.8723	√	√
	(0.0110)	(0.0115)	(0.0120)	(0.0128)	(0.0135)	(0.0135)			
Sprinkle-irrigated Rate									
Tribal2015	-0.2648***	-0.2797***	-0.2855***	-0.3068***	-0.3094***	-0.3205***	1.4005	√	√
	(0.0277)	(0.0301)	(0.0333)	(0.0388)	(0.0458)	(0.0429)			
High-value Crops Rate									
Tribal2015	-0.0173**	-0.0151*	-0.0130	-0.0218*	-0.0387***	-0.0329**	1.1307	√	√
	(0.0082)	(0.0089)	(0.0100)	(0.0116)	(0.0135)	(0.0131)			

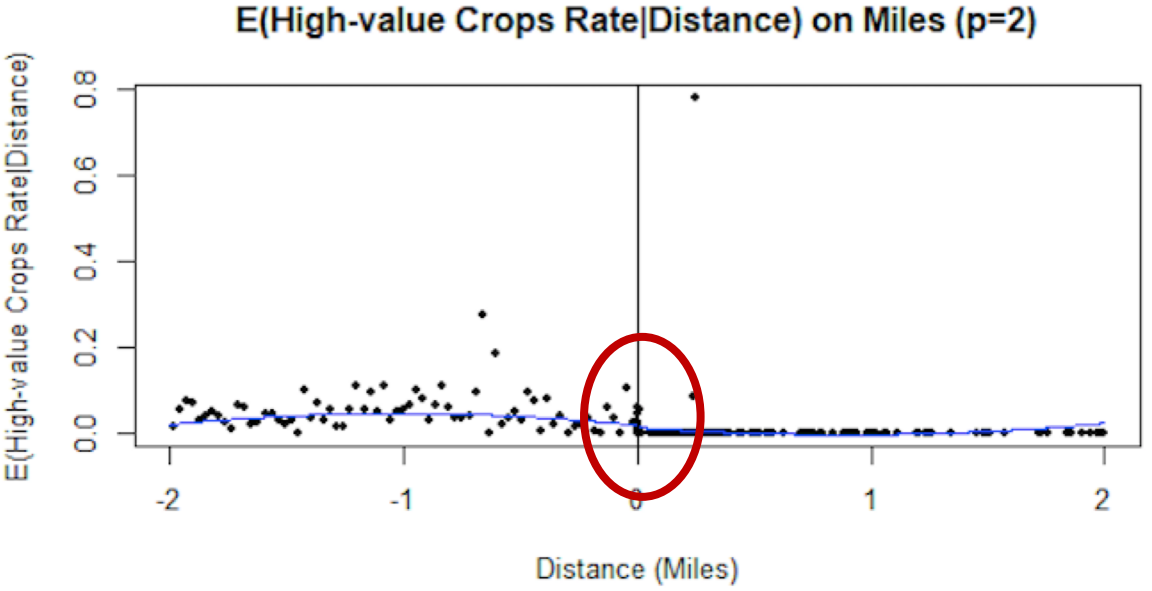
Notes: Coefficients significantly different from zero are denoted by the following system: * 10%, ** 5%, and *** 1%. Robust standard errors are provided in the parenthesis.

~-30 percentage points

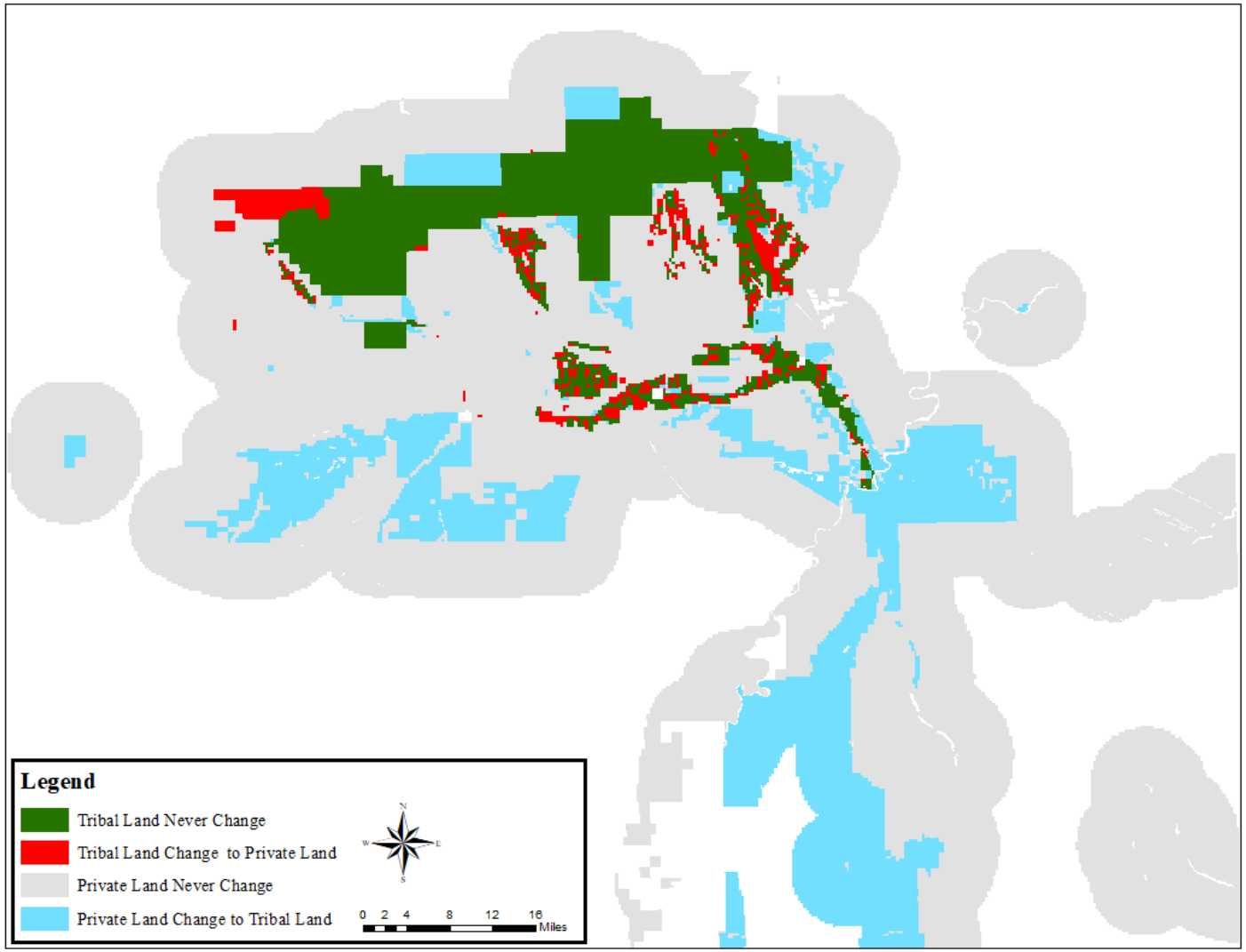

E(Irrigation Rate|Distance) on Miles (p=2)
E(Irrigation Rate|Distance)
0.0
0.2
0.4
0.6
0.8
1.0
-2
-1
0
1
2
Distance (Miles)


E(Soilquality|Distance) on Miles (p=2)
E(Soilquality|Distance)
2
4
6
8
10
-2
-1
0
1
2
Distance (Miles)

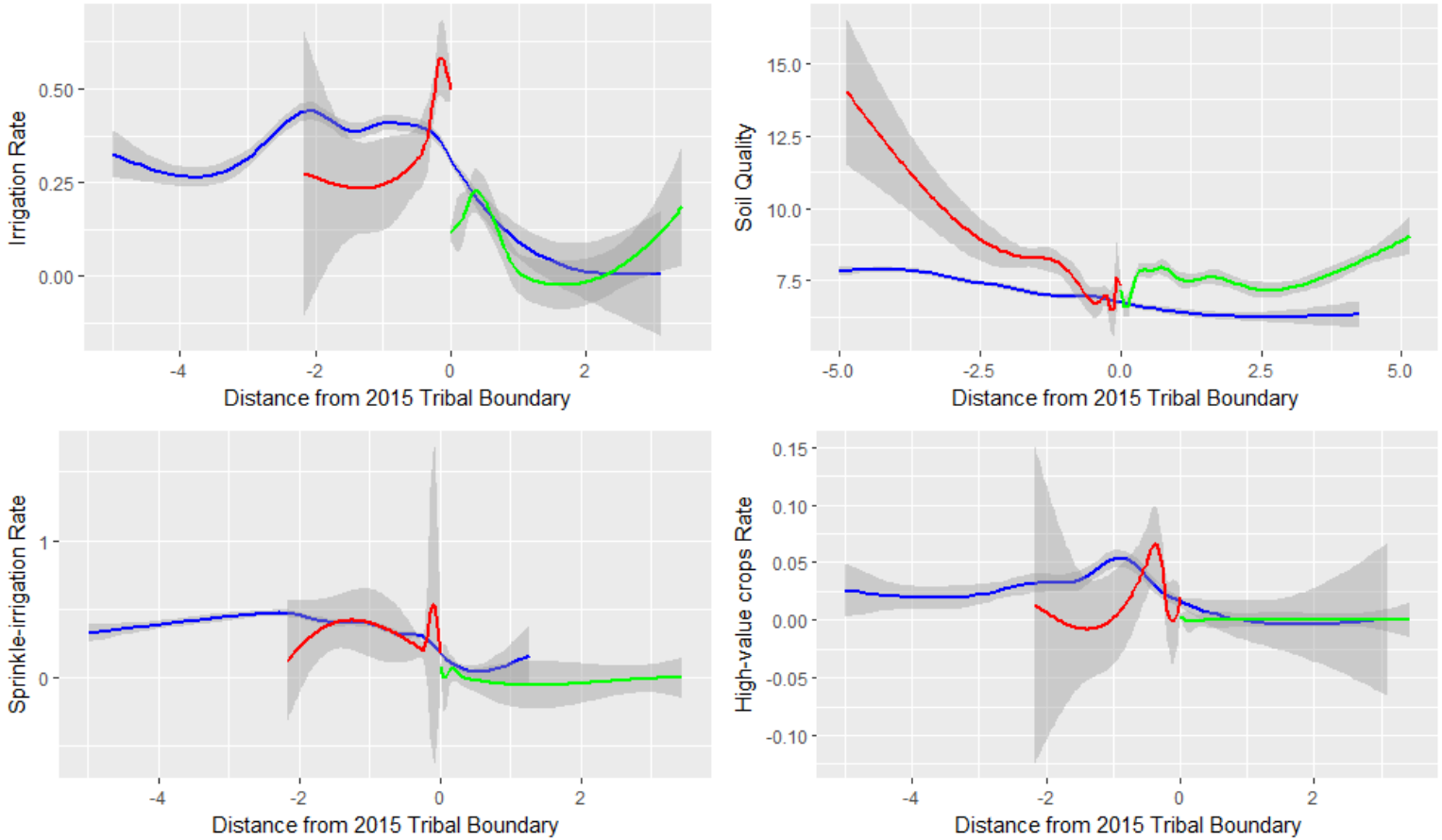

E(Sprinkle-irrigated Rate|Distance) on Miles (p=2)
E(Sprinkle-irrigated Rate|Distance)
0.0
0.2
0.4
0.6
0.8
1.0
-2
-1
0
1
2
Distance (Miles)


E(High-value Crops Rate|Distance) on Miles (p=2)
E(High-value Crops Rate|Distance)
0.0
0.2
0.4
0.6
0.8
-2
-1
0
1
2
Distance (Miles)

Land Ownership Changes



Land Ownership Changes



Red line: Tribal→Private

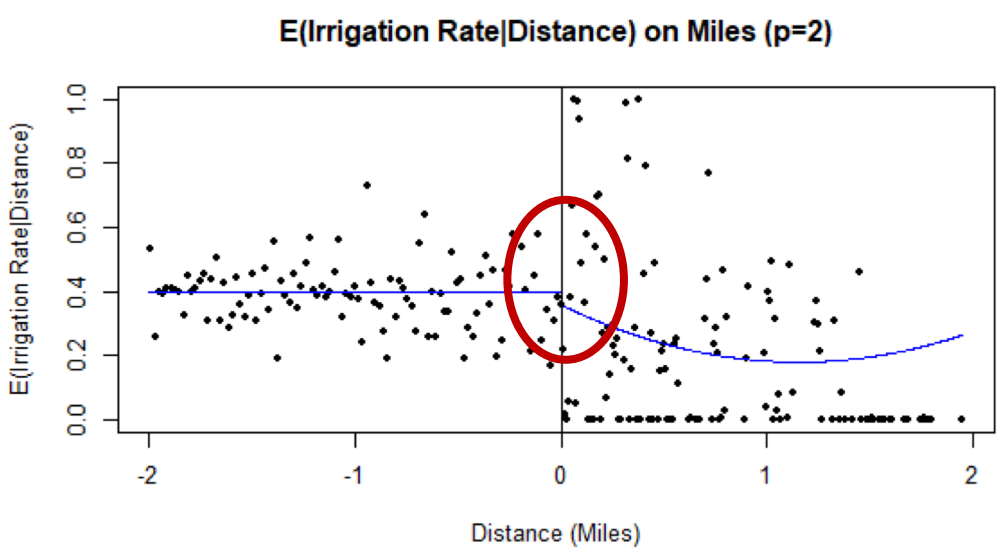
Green line: Private→Tribal

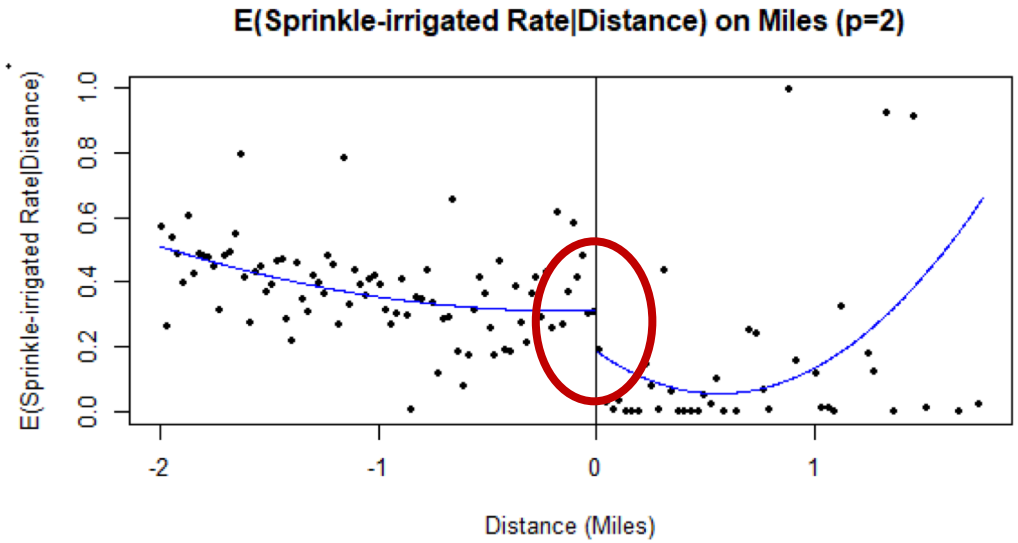
Blue line: No ownership change

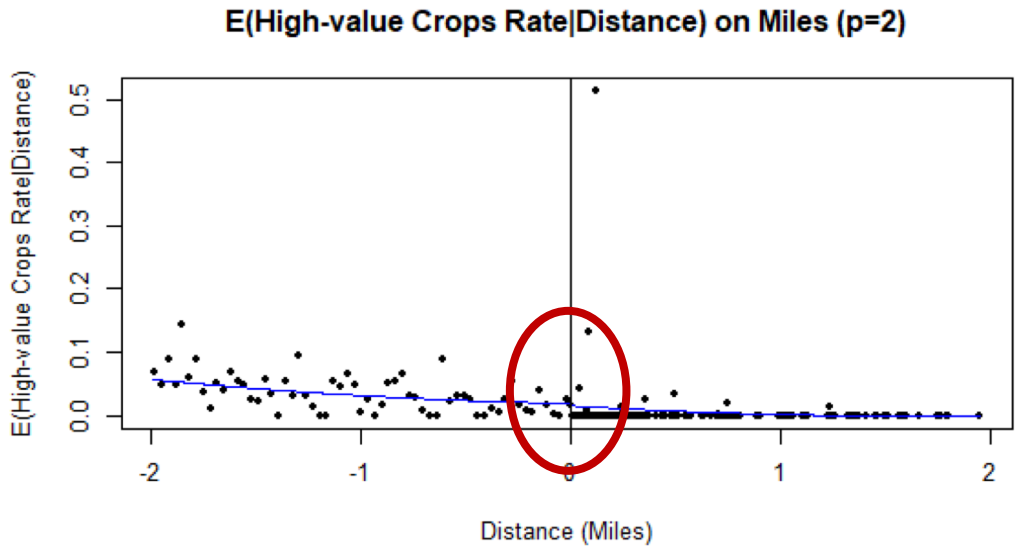
1905 “no ownership change land” Sharp RD results

Table 4 1905 Allotment Border Non-parametric RD Results (Second order polynomial)

Sample Within	Estimated Average Treatment Effects							Control Variables	
	<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth			
							Optimal Miles	Townships	Soil Productivity
Irrigation Rate									
Allotment1905	-0.0286*	-0.0344**	-0.0409**	-0.0336	-0.0097	-0.0237	1.5681	√	√
	(0.0160)	(0.0171)	(0.0190)	(0.0220)	(0.0258)	(0.0235)			
Sprinkle-irrigated Rate									
Allotment1905	-0.0931***	-0.1076***	-0.1356***	-0.1460***	-0.1410***	-0.1372***	0.9657	√	√
	(0.0167)	(0.0181)	(0.0202)	(0.0236)	(0.0280)	(0.0287)			
High-value Cropland Rate									
Allotment1905	0.0023	-0.0024	-0.0045	-0.0021	-0.0094	-0.0019	2.1353	√	√
	(0.0049)	(0.0052)	(0.0058)	(0.0067)	(0.0077)	(0.0065)			


E(Irrigation Rate|Distance) on Miles (p=2)
E(Irrigation Rate|Distance)
0.0
0.2
0.4
0.6
0.8
1.0
-2
-1
0
1
2
Distance (Miles)


E(Sprinkle-irrigated Rate|Distance) on Miles (p=2)
E(Sprinkle-irrigated Rate|Distance)
0.0
0.2
0.4
0.6
0.8
1.0
-2
-1
0
1
Distance (Miles)


E(High-value Crops Rate|Distance) on Miles (p=2)
E(High-value Crops Rate|Distance)
0.0
0.1
0.2
0.3
0.4
0.5
-2
-1
0
1
2
Distance (Miles)

2015 “no ownership change land” Fuzzy RD results

Table 5 2015 Tribal Boundary Non-parametric RD Results (Second order polynomial)

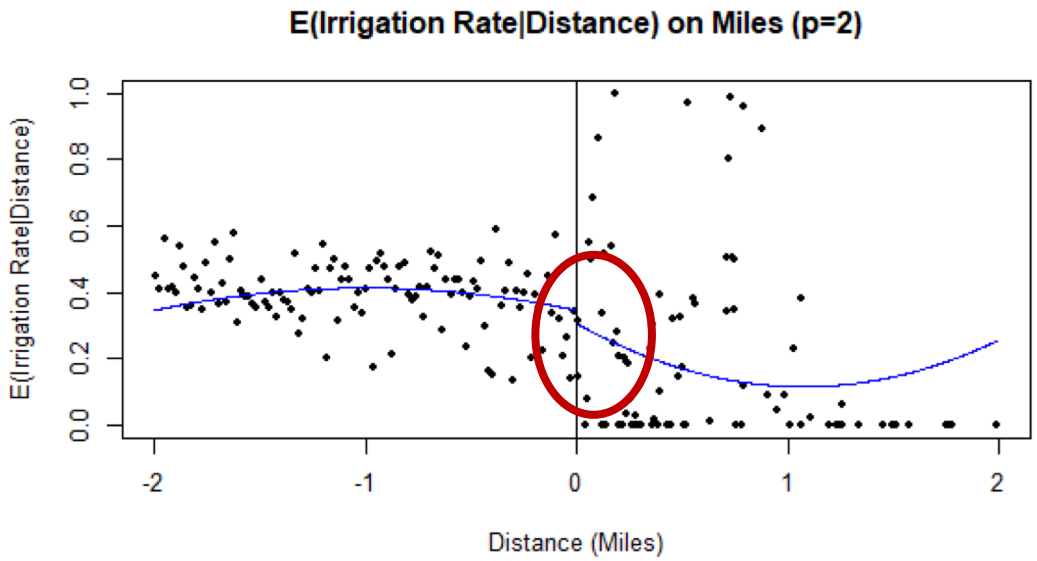
Sample Within	Estimated Average Treatment Effects							Control Variables	
	<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth	Optimal Miles	Townships	Soil Productivity
Irrigation Rate									
Tribal2015	-0.0679***	-0.0786***	-0.0632***	-0.0465**	-0.0400	-0.0407	0.9732	√	√
	(0.0196)	(0.0204)	(0.0215)	(0.0231)	(0.0248)	(0.0249)			
Sprinkle-irrigated Rate									
Tribal2015	-0.2014***	-0.2062***	-0.2008***	-0.2045***	-0.1986***	-0.1924***	0.4985	√	√
	(0.0219)	(0.0230)	(0.0242)	(0.0259)	(0.0277)	(0.0285)			
High-value Cropland Rate									
Tribal2015	-0.0062	-0.0041	-0.0022	-0.0090	-0.0203**	-0.0184**	1.1439	√	√
	(0.0064)	(0.0068)	(0.0073)	(0.0079)	(0.0082)	(0.0082)			

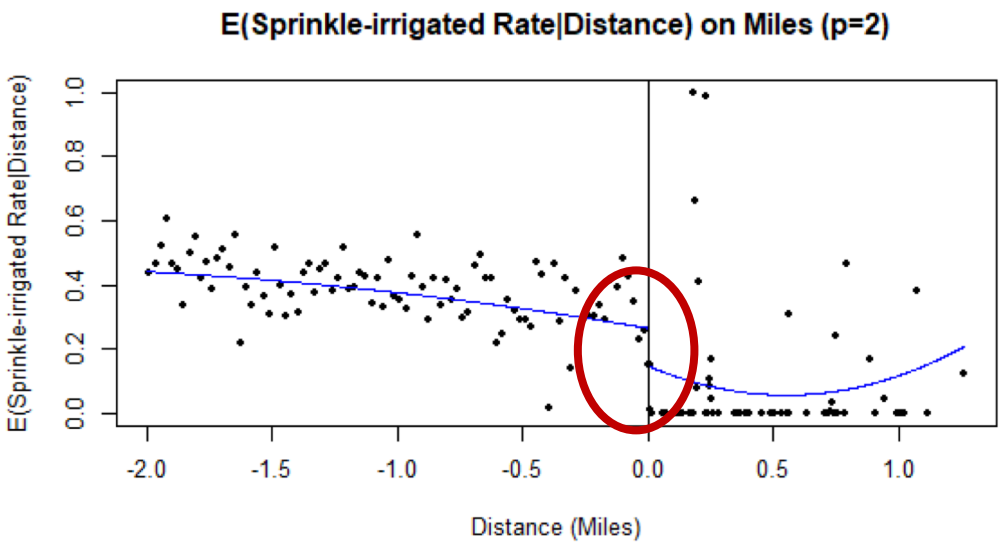
2015 “no ownership change land” Fuzzy RD results

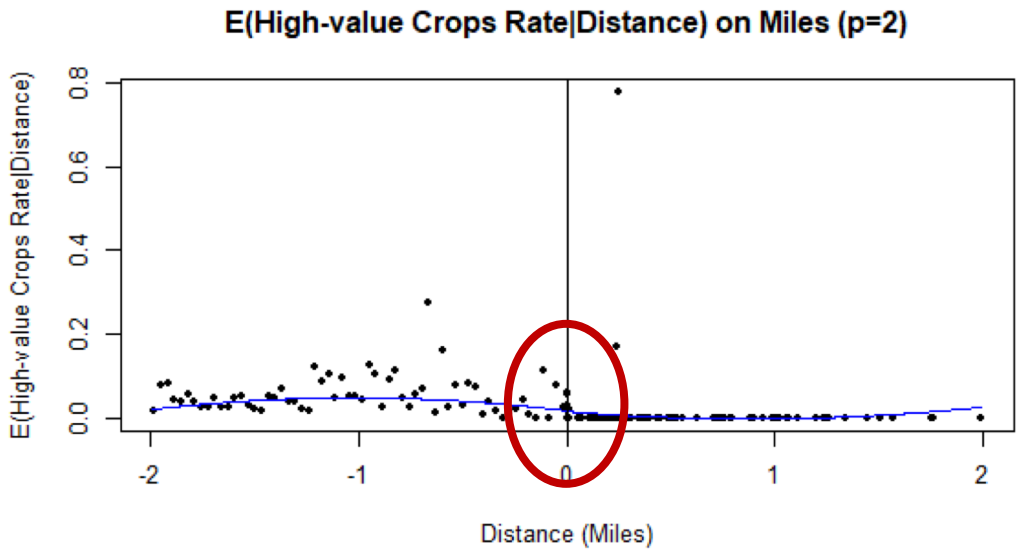
Table 5 2015 Tribal Boundary Non-parametric RD Results (Second order polynomial)

Sample Within	Estimated Average Treatment Effects							Control Variables	
	<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth	Optimal Miles	Townships	Soil Productivity
Irrigation Rate									
Tribal2015	-0.0679***	-0.0786***	-0.0632***	-0.0465**	-0.0400	-0.0407	0.9732	√	√
	(0.0196)	(0.0204)	(0.0215)	(0.0231)	(0.0248)	(0.0249)			
Sprinkle-irrigated Rate									
Tribal2015	-0.2014***	-0.2062***	-0.2008***	-0.2045***	-0.1986***	-0.1924***	0.4985	√	√
	(0.0219)	(0.0230)	(0.0242)	(0.0259)	(0.0277)	(0.0285)			
High-value Cropland Rate									
Tribal2015	-0.0062	-0.0041	-0.0022	-0.0090	-0.0203**	-0.0184**	1.1439	√	√
	(0.0064)	(0.0068)	(0.0073)	(0.0079)	(0.0082)	(0.0082)			

~-20 percentage points


E(Irrigation Rate|Distance) on Miles (p=2)
E(Irrigation Rate|Distance)
0.0
0.2
0.4
0.6
0.8
1.0
-2
-1
0
1
2
Distance (Miles)


E(Sprinkle-irrigated Rate|Distance) on Miles (p=2)
E(Sprinkle-irrigated Rate|Distance)
0.0
0.2
0.4
0.6
0.8
1.0
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
Distance (Miles)


E(High-value Crops Rate|Distance) on Miles (p=2)
E(High-value Crops Rate|Distance)
0.0
0.2
0.4
0.6
0.8
-2
-1
0
1
2
Distance (Miles)

Conclusion

- The original allocation provided land of similar quality across the border.
- Tribal lands are around 7 percentage points less likely to be irrigated today.
- Conditional on land being irrigated, tribal lands have around 30 percentage points lower rates of capital-intensive sprinkle irrigation.
- Tribal land is also less likely to grow high-value crops.
- These results hold with the “no ownership change land” RD as well.

- These results suggest that difficulties in securing capital for irrigation infrastructure and equipment may help to explain lagging agricultural development on reservations.

Appendix

Table A1 Crops Value Classification

Crops	Crop Value	Crop Value Indicator
Alfalfa	Low	0
Beans	High	1
Berries	High	1
Corn	High	1
Dry Alfalfa	Low	0
Dry Beans	High	1
Dry Grain	High	1
Dry Grain/Seeds	High	1
Dry Oats	High	1
Dry Safflower	High	1
Fallow-Irrigated Ag	Low	0
Fallow-Irrigated Land	Low	0
Grain	High	1
Grass Hay	Low	0
Grass Hay-sub-irrigated	Low	0
Idle-Irrigated Ag	Low	0
Idle-Irrigated Land	Low	0
Idle-Irrigated Pasture	Low	0
Melon/Pumpkin/Squash	High	1
Oats	High	1
Onions	High	1
Orchard	High	1
Other Horticulture	High	1
Other Vegetables	High	1
Pasture	Low	0
Pasture-sub-irrigated	Low	0
Potatoes	High	1
Safflower	High	1
Sorghum	High	1
Tomatoes	High	1
Turf Farms	High	1
Vineyard	High	1

Table A2-1 1905 Boundary Estimated Average Treatment Effects

Sample Within	Soil Productivity index (2012)					
	<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth
First order polynomial						Optimal Miles
Allotment1905	0.3444***	0.2574***	0.1352**	0.0661	-0.0332	0.3444	0.8308
	(0.0583)	(0.0628)	(0.0696)	(0.0815)	(0.1043)	(0.0583)	
Second order polynomial							
Allotment1905	0.1329**	0.0464	0.0144	0.0075	0.0130	0.1329	1.3465
	(0.0725)	(0.0786)	(0.0876)	(0.1003)	(0.1141)	(0.0725)	
Third order polynomial							
Allotment1905	-0.0171	-0.0108	0.0215	-0.0279	0.0090	-0.0171	1.7291
	(0.0862)	(0.0933)	(0.1019)	(0.1113)	(0.1179)	(0.0862)	
Fourth order polynomial							
Allotment1905	-0.0099	0.0221	-0.0052	0.0166	-0.0012	-0.0099	2.1202
	(0.0982)	(0.1045)	(0.1111)	(0.1163)	(0.1257)	(0.0982)	
Observations (out/in)	(26289/11220)	(22426/11153)	(18058/10743)	(13015/9795)	(7214/7948)		

Table A2-2 1905 Boundary Estimated Average Treatment Effects

Sample Within	Agricultural Rate (2012)					
	<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth
First order polynomial						Optimal Miles
Allotment1905	0.0689***	0.0730***	0.0654***	0.0444***	0.0269	0.0273	0.5199
	(0.0094)	(0.0100)	(0.0111)	(0.0131)	(0.0177)	(0.0189)	
Second order polynomial							
Allotment1905	0.0660***	0.0560***	0.0339**	0.0338**	0.0258	0.0269	1.1982
	(0.0116)	(0.0126)	(0.0143)	(0.0167)	(0.0197)	(0.0184)	
Third order polynomial							
Allotment1905	0.0458***	0.0280*	0.0338**	0.0255	0.0267	0.0278	2.1766
	(0.0140)	(0.0153)	(0.0170)	(0.0189)	(0.0201)	(0.0185)	
Fourth order polynomial							
Allotment1905	0.0208	0.0301*	0.0311*	0.0258	0.0311	0.0259	1.9167
	(0.0162)	(0.0175)	(0.0188)	(0.0198)	(0.0208)	(0.0198)	
Control Variables Townships	√	√	√	√	√	√	
Soil Productivity	√	√	√	√	√	√	
Observations (out/in)	(7261/4685)	(6638/4683)	(5848/4653)	(4730/4574)	(2874/4357)		

Table A2-3 1905 Boundary Estimated Average Treatment Effects

Sample Within	Irrigation Rate (2012)					
	<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth
First order polynomial						Optimal Miles
Allotment1905	0.0061	0.0151	0.0175	0.0123	0.0273	0.0188	0.7420
	(0.0123)	(0.0130)	(0.0142)	(0.0166)	(0.0219)	(0.0210)	
Second order polynomial							
Allotment1905	0.0220	0.0168	0.0109	0.0140	0.0376	0.0371	1.0629
	(0.0149)	(0.0161)	(0.0179)	(0.0208)	(0.0245)	(0.0242)	
Third order polynomial							
Allotment1905	0.0168	0.0129	0.0144	0.0281	0.0378	0.0376	1.2583
	(0.0178)	(0.0192)	(0.0211)	(0.0235)	(0.0253)	(0.0250)	
Fourth order polynomial							
Allotment1905	0.0060	0.0132	0.0274	0.0399	0.0330	0.0368	1.5393
	(0.0203)	(0.0217)	(0.0233)	(0.0247)	(0.0263)	(0.0253)	
Control Variables Townships	√	√	√	√	√	√	
Soil Productivity	√	√	√	√	√	√	
Observations (out/in)	(7113/4433)	(6673/4433)	(5962/4433)	(4874/4395)	(2992/4236)		

Table A2-4 1905 Boundary Estimated Average Treatment Effects

Sample Within	Sprinkle-irrigated Rate (2012)					
	<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth
First order polynomial						Optimal Miles
Allotment1905	-0.0944***	-0.0882***	-0.0921***	-0.1141***	-0.1434***	-0.1392***	0.5520
	(0.0128)	(0.0136)	(0.0150)	(0.0178)	(0.0241)	(0.0255)	
Second order polynomial							
Allotment1905	-0.0867***	-0.0996***	-0.1253***	-0.1337***	-0.1310***	-0.1353***	1.2449
	(0.0158)	(0.0172)	(0.0194)	(0.0227)	(0.0271)	(0.0266)	
Third order polynomial							
Allotment1905	-0.1143***	-0.1334***	-0.1358***	-0.1455***	-0.1249***	-0.1249***	0.8952
	(0.0192)	(0.0208)	(0.0231)	(0.0258)	(0.0278)	(0.0278)	
Fourth order polynomial							
Allotment1905	-0.1444***	-0.1422***	-0.1372***	-0.1311***	-0.1122***	-0.1232***	1.3258
	(0.0221)	(0.0238)	(0.0256)	(0.0271)	(0.0286)	(0.0278)	
Control Variables Townships	√	√	√	√	√	√	
Soil Productivity	√	√	√	√	√	√	
Observations (out/in)	(5157/2977)	(4822/2977)	(4331/2977)	(3582/2976)	(2195/2906)		

Table A2-5 1905 Boundary Estimated Average Treatment Effects

Sample Within	High-value Crops Rate (2012)					
	<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth
First order polynomial						Optimal Miles
Allotment1905	0.0037	0.0058	0.0028	0.0003	-0.0038	-0.0017	0.7380
	(0.0038)	(0.0040)	(0.0043)	(0.0050)	(0.0066)	(0.0063)	
Second order polynomial							
Allotment1905	0.0053	0.0006	-0.0012	0.0009	-0.0065	-0.0049	1.2374
	(0.0046)	(0.0050)	(0.0055)	(0.0063)	(0.0074)	(0.0070)	
Third order polynomial							
Allotment1905	-0.0019	-0.0025	0.0002	-0.0041	-0.0073	-0.0063	1.3142
	(0.0055)	(0.0059)	(0.0065)	(0.0072)	(0.0077)	(0.0075)	
Fourth order polynomial							
Allotment1905	-0.0047	-0.0003	-0.0014	-0.0052	-0.0086	-0.0060	1.6295
	(0.0063)	(0.0067)	(0.0072)	(0.0076)	(0.0083)	(0.0076)	
Control Variables Townships	√	√	√	√	√	√	
Soil Productivity	√	√	√	√	√	√	
Observations (out/in)	(6324/3890)	(5908/3890)	(5285/3890)	(4320/3858)	(2650/3730)		

Table A3-1 2015 Boundary Estimated Average Treatment Effects

Sample Within	Soil Productivity index (2012)						
	<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth	Optimal Miles
First order polynomial							
Tribal2015	0.2971***	0.2545***	0.2483***	0.2692***	0.2969***	0.2914***	1.2312
	(0.0508)	(0.0538)	(0.0579)	(0.0644)	(0.0743)	(0.0696)	
Second order polynomial							
Tribal2015	0.2108***	0.2476***	0.2714***	0.3115***	0.3456***	0.2914***	2.1344
	(0.0591)	(0.0625)	(0.0670)	(0.0726)	(0.0777)	(0.0700)	
Third order polynomial							
Tribal2015	0.2610***	0.2767***	0.3113***	0.3111***	0.3436***	0.3188***	2.1664
	(0.0660)	(0.0693)	(0.0730)	(0.0766)	(0.0786)	(0.0753)	
Fourth order polynomial							
Tribal2015	0.2897***	0.3107***	0.3209***	0.3361***	0.3187***	0.3228***	2.9354
	(0.0712)	(0.0738)	(0.0763)	(0.0781)	(0.0808)	(0.0759)	
Observations (out/in)	(60944/28157)	(51606/27051)	(41370/25401)	(29715/22680)	(16532/18171)		

Table A3-2 2015 Boundary Estimated Average Treatment Effects

Sample Within	Agricultural Rate (2012)						
	<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth	Optimal Miles
First order polynomial							
Tribal2015	0.0904***	0.0905***	0.0839***	0.0606**	-0.0127	-0.0019	0.8988
	(0.0177)	(0.0190)	(0.0208)	(0.0238)	(0.0308)	(0.0334)	
Second order polynomial							
Tribal2015	0.0822***	0.0672***	0.0451*	0.0001	-0.0040	-0.0044	1.2222
	(0.0227)	(0.0245)	(0.0268)	(0.0309)	(0.0373)	(0.0365)	
Third order polynomial							
Tribal2015	0.0461*	0.0252	-0.0007	-0.0237	0.0154	-0.0092	2.3739
	(0.0272)	(0.0293)	(0.0321)	(0.0360)	(0.0378)	(0.0342)	
Fourth order polynomial							
Tribal2015	0.0125	-0.0041	-0.0205	-0.0036	0.0505	0.0030	1.8585
	(0.0314)	(0.0336)	(0.0361)	(0.0379)	(0.0385)	(0.0380)	
Control Variables Townships	√	√	√	√	√	√	
Soil Productivity	√	√	√	√	√	√	
Observations (out/in)	(9380/5267)	(8861/5252)	(8200/5202)	(6920/5051)	(4727/4838)		

Table A3-3 2015 Boundary Estimated Average Treatment Effects

Sample Within	Irrigation Rate (2012)						
	<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth	Optimal Miles
First order polynomial							
Tribal2015	-0.0705***	-0.0691***	-0.0774***	-0.0739***	-0.0704***	-0.0673***	0.9200
	(0.0099)	(0.0102)	(0.0107)	(0.0116)	(0.0130)	(0.0136)	
Second order polynomial							
Tribal2015	-0.0707***	-0.0793***	-0.0744***	-0.0701***	-0.0668***	-0.0666***	0.8723
	(0.0110)	(0.0115)	(0.0120)	(0.0128)	(0.0135)	(0.0135)	
Third order polynomial							
Tribal2015	-0.0793***	-0.0732***	-0.0681***	-0.0693***	-0.0652***	-0.0655***	0.9355
	(0.0120)	(0.0124)	(0.0128)	(0.0133)	(0.0137)	(0.0136)	
Fourth order polynomial							
Tribal2015	-0.0707***	-0.0657***	-0.0691***	-0.0663***	-0.0634***	-0.0646***	1.1728
	(0.0127)	(0.0130)	(0.0133)	(0.0135)	(0.0141)	(0.0137)	
Control Variables Townships	√	√	√	√	√	√	
Soil Productivity	√	√	√	√	√	√	
Observations (out/in)	(8455/4312)	(8151/4312)	(7549/4304)	(6466/4225)	(4427/4141)		

Table A3-4 2015 Boundary Estimated Average Treatment Effects

Sample Within	Sprinkle-irrigated Rate (2012)						
	<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth	Optimal Miles
First order polynomial							
Tribal2015	-0.2464***	-0.2526***	-0.2656***	-0.2785***	-0.3159***	-0.3160***	0.8422
	(0.0218)	(0.0232)	(0.0252)	(0.0292)	(0.0388)	(0.0406)	
Second order polynomial							
Tribal2015	-0.2648***	-0.2797***	-0.2855***	-0.3068***	-0.3094***	-0.3205***	1.4005
	(0.0277)	(0.0301)	(0.0333)	(0.0388)	(0.0458)	(0.0429)	
Third order polynomial							
Tribal2015	-0.2896***	-0.2961***	-0.3092***	-0.3210***	-0.3040***	-0.3151***	1.6226
	(0.0342)	(0.0372)	(0.0406)	(0.0447)	(0.0463)	(0.0458)	
Fourth order polynomial							
Tribal2015	-0.3017***	-0.3059***	-0.3157***	-0.3074***	-0.2947***	-0.3044***	1.6620
	(0.0399)	(0.0425)	(0.0448)	(0.0464)	(0.0474)	(0.0463)	
Control Variables Townships	√	√	√	√	√	√	
Soil Productivity	√	√	√	√	√	√	
Observations (out/in)	(6275/2594)	(6049/2594)	(5713/2588)	(4912/2584)	(3362/2574)		

Table A3-5 2015 Boundary Estimated Average Treatment Effects

Sample Within	High-value Crops Rate (2012)						
	<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth	Optimal Miles
First order polynomial							
Tribal2015	-0.0309***	-0.0259***	-0.0213***	-0.0149*	-0.0315***	-0.0142	1.2029
	(0.0065)	(0.0069)	(0.0075)	(0.0088)	(0.0115)	(0.0104)	
Second order polynomial							
Tribal2015	-0.0173**	-0.0151*	-0.0130	-0.0218*	-0.0387***	-0.0329**	1.1307
	(0.0082)	(0.0089)	(0.0100)	(0.0116)	(0.0135)	(0.0131)	
Third order polynomial							
Tribal2015	-0.0130	-0.0153	-0.0223*	-0.0372***	-0.0393***	-0.0274**	1.9070
	(0.0102)	(0.0111)	(0.0121)	(0.0133)	(0.0138)	(0.0132)	
Fourth order polynomial							
Tribal2015	-0.0187	-0.0230*	-0.0339**	-0.0382***	-0.0337**	-0.0395***	1.8002
	(0.0119)	(0.0126)	(0.0134)	(0.0138)	(0.0145)	(0.0138)	
Control Variables Townships	√	√	√	√	√	√	
Soil Productivity	√	√	√	√	√	√	
Observations (out/in)	(7575/3667)	(7298/3667)	(6764/3659)	(5799/3593)	(3990/3535)		

Table A4-1 1905 Boundary Estimated Average Treatment Effects

Sample Within	Soil Productivity index						
	<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth	
							Optimal Miles
First order polynomial							
Allotment1905	0.1648**	0.0823	-0.0591	-0.0761	-0.1235	0.1648	1.0784
	(0.0641)	(0.0688)	(0.0760)	(0.0885)	(0.1119)	(0.0641)	
Second order polynomial							
Allotment1905	-0.0340	-0.1382	-0.1215	-0.0845	-0.0836	-0.0340	1.5496
	(0.0791)	(0.0856)	(0.0950)	(0.1081)	(0.1216)	(0.0791)	
Third order polynomial							
Allotment1905	-0.1927**	-0.1363	-0.0573	-0.1064	-0.0917	-0.1927	2.0394
	(0.0937)	(0.1010)	(0.1099)	(0.1191)	(0.1253)	(0.0937)	
Fourth order polynomial							
Allotment1905	-0.1149	-0.0445	-0.0829	-0.0649	-0.1155	-0.1149	2.3801
	(0.1061)	(0.1126)	(0.1190)	(0.1238)	(0.1339)	(0.1061)	
Observations (out/in)	(22738/9212)	(19386/9145)	(15421/8735)	(11050/7800)	(6041/6092)		

Table A4-2 1905 Boundary Estimated Average Treatment Effects

Sample Within		Irrigation Rate						
		<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth	
								Optimal Miles
First order polynomial								
Allotment1905		-0.0498***	-0.0397***	-0.0364**	-0.0409**	-0.0179	-0.0139	0.4895
		(0.0133)	(0.0140)	(0.0152)	(0.0177)	(0.0232)	(0.0250)	
Second order polynomial								
Allotment1905		-0.0286*	-0.0344**	-0.0409**	-0.0336	-0.0097	-0.0237	1.5681
		(0.0160)	(0.0171)	(0.0190)	(0.0220)	(0.0258)	(0.0235)	
Third order polynomial								
Allotment1905		-0.0338*	-0.0372*	-0.0342	-0.0165	-0.0106	-0.0124	1.3919
		(0.0188)	(0.0203)	(0.0223)	(0.0248)	(0.0266)	(0.0264)	
Fourth order polynomial								
Allotment1905		-0.0430**	-0.0345	-0.0169	-0.0061	-0.0144	-0.0110	1.6034
		(0.0215)	(0.0229)	(0.0246)	(0.0260)	(0.0277)	(0.0265)	
Control Variables	Townships	√	√	√	√	√	√	
	Soil Productivity	√	√	√	√	√	√	
Observations (out/in)		(6732/3112)	(6329/3112)	(5641/3112)	(4580/3074)	(2794/2944)		

Table A4-3 1905 Boundary Estimated Average Treatment Effects

Sample Within		Sprinkle-irrigated Rate						
		<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth	
								Optimal Miles
First order polynomial								
Allotment1905		-0.1043***	-0.0966***	-0.0998***	-0.1241***	-0.1526***	-0.1482***	0.4728
		(0.0137)	(0.0145)	(0.0159)	(0.0187)	(0.0250)	(0.0278)	
Second order polynomial								
Allotment1905		-0.0931***	-0.1076***	-0.1356***	-0.1460***	-0.1410***	-0.1372***	0.9657
		(0.0167)	(0.0181)	(0.0202)	(0.0236)	(0.0280)	(0.0287)	
Third order polynomial								
Allotment1905		-0.1236***	-0.1437***	-0.1485***	-0.1552***	-0.1347***	-0.1341***	1.0743
		(0.0200)	(0.0217)	(0.0240)	(0.0268)	(0.0287)	(0.0288)	
Fourth order polynomial								
Allotment1905		-0.1556***	-0.1552***	-0.1479***	-0.1405***	-0.1230***	-0.1163***	0.7911
		(0.0230)	(0.0247)	(0.0266)	(0.0281)	(0.0296)	(0.0299)	
Control Variables	Townships	√	√	√	√	√	√	
	Soil Productivity	√	√	√	√	√	√	
Observations (out/in)		4996/1987)	(4672/1987)	(4186/1987)	(3452/1987)	(2118/1937)		

Table A4-4 1905 Boundary Estimated Average Treatment Effects

Sample Within		High-value Cropland Rate (2012)						
		<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth	
								Optimal Miles
First order polynomial								
Allotment1905		0.0005	0.0027	-0.0002	-0.0029	-0.0064	-0.0023	0.9110
		(0.0041)	(0.0043)	(0.0046)	(0.0053)	(0.0069)	(0.0060)	
Second order polynomial								
Allotment1905		0.0023	-0.0024	-0.0045	-0.0021	-0.0094	-0.0019	2.1353
		(0.0049)	(0.0052)	(0.0058)	(0.0067)	(0.0077)	(0.0065)	
Third order polynomial								
Allotment1905		-0.0051	-0.0059	-0.0030	-0.0068	-0.0102	-0.0027	2.2357
		(0.0058)	(0.0062)	(0.0068)	(0.0075)	(0.0081)	(0.0072)	
Fourth order polynomial								
Allotment1905		-0.0081	-0.0035	-0.0042	-0.0080	-0.0117	-0.0091	1.6392
		(0.0066)	(0.0070)	(0.0075)	(0.0079)	(0.0086)	(0.0080)	
Control Variables	Townships	√	√	√	√	√	√	
	Soil Productivity	√	√	√	√	√	√	
Observations (out/in)		(6039/2707)	(5660/2707)	(5059/2707)	(4114/2675)	(2521/2575)		

Table A5-1 2015 Boundary Estimated Average Treatment Effects

Sample Within	Soil Productivity index						
	<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth	Optimal Miles
First order polynomial Tribal2015	0.0756 (0.1032)	0.1417 (0.1106)	0.2686** (0.1240)	0.4608*** (0.1483)	0.6642*** (0.1931)	0.5935*** (0.1721)	1.1773
Second order polynomial Tribal2015	0.2834** (0.1374)	0.4105*** (0.1473)	0.5213*** (0.1640)	0.7119*** (0.1889)	0.8063*** (0.2181)	0.6144*** (0.1793)	2.0498
Third order polynomial Tribal2015	0.5042*** (0.1667)	0.5617*** (0.1774)	0.7154*** (0.1931)	0.7242*** (0.2115)	0.7899*** (0.2248)	0.7429*** (0.2002)	2.4715
Fourth order polynomial Tribal2015	0.6130*** (0.1897)	0.7155*** (0.1988)	0.7520*** (0.2106)	0.7787*** (0.2208)	0.7063*** (0.2331)	0.7563*** (0.2113)	2.8017
Observations (out/in)	(59963/10669)	(50629/10643)	(40393/10218)	(28765/9092)	(15804/7450)		

Table A5-2 2015 Boundary Estimated Average Treatment Effects

Sample Within		Irrigation Rate						
		<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth	Optimal Miles
First order polynomial Tribal2015		-0.0847*** (0.0171)	-0.0767*** (0.0176)	-0.0841*** (0.0186)	-0.0668*** (0.0204)	-0.0454* (0.0234)	-0.0393 (0.0247)	0.7263
Second order polynomial Tribal2015		-0.0679*** (0.0196)	-0.0786*** (0.0204)	-0.0632*** (0.0215)	-0.0465** (0.0231)	-0.0400 (0.0248)	-0.0407 (0.0249)	0.9732
Third order polynomial Tribal2015		-0.0725*** (0.0216)	-0.0567** (0.0224)	-0.0424* (0.0233)	-0.0434* (0.0244)	-0.0410 (0.0253)	-0.0411 (0.0250)	1.3659
Fourth order polynomial Tribal2015		-0.0483** (0.0231)	-0.0359 (0.0237)	-0.0426* (0.0243)	-0.0402 (0.0249)	-0.0407 (0.0262)	-0.0414 (0.0252)	1.4557
Control Variables	Townships	√	√	√	√	√	√	
	Soil Productivity	√	√	√	√	√	√	
Observations (out/in)		(7896/2931)	(7592/2931)	(6990/2930)	(5909/2891)	(3898/2855)		

Table A5-3 2015 Boundary Estimated Average Treatment Effects

Sample Within		Sprinkle-irrigated Rate						
		<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth	Optimal Miles
First order polynomial Tribal2015		-0.1934*** (0.0191)	-0.1958*** (0.0199)	-0.2027*** (0.0209)	-0.2009*** (0.0228)	-0.2092*** (0.0261)	-0.1926*** (0.0287)	0.7918
Second order polynomial Tribal2015		-0.2014*** (0.0219)	-0.2062*** (0.0230)	-0.2008*** (0.0242)	-0.2045*** (0.0259)	-0.1986*** (0.0277)	-0.1924*** (0.0285)	0.4985
Third order polynomial Tribal2015		-0.2062*** (0.0243)	-0.2025*** (0.0253)	-0.2052*** (0.0263)	-0.2084*** (0.0274)	-0.1937*** (0.0282)	-0.1658*** (0.0308)	0.4418
Fourth order polynomial Tribal2015		-0.2034*** (0.0260)	-0.2015*** (0.0268)	-0.2054*** (0.0275)	-0.1977*** (0.0280)	-0.1814*** (0.0293)	-0.1619*** (0.0336)	0.4563
Control Variables	Townships	√	√	√	√	√	√	
	Soil Productivity	√	√	√	√	√	√	
Observations (out/in)		(5844/1787)	(5618/1787)	(5282/1787)	(4483/1787)	(2947/1787)		

Table A5-4 2015 Boundary Estimated Average Treatment Effects

Sample Within		High-value Cropland Rate (2012)						
		<5 Miles	<4 Miles	<3 Miles	<2 Miles	<1 Miles	Optimal Bandwidth	Optimal Miles
First order polynomial Tribal2015		-0.0190*** (0.0055)	-0.0138** (0.0057)	-0.0091 (0.0061)	-0.0030 (0.0069)	-0.0169** (0.0079)	-0.0129* (0.0077)	1.1634
Second order polynomial Tribal2015		-0.0062 (0.0064)	-0.0041 (0.0068)	-0.0022 (0.0073)	-0.0090 (0.0079)	-0.0203** (0.0082)	-0.0184** (0.0082)	1.1439
Third order polynomial Tribal2015		-0.0025 (0.0073)	-0.0040 (0.0077)	-0.0089 (0.0080)	-0.0189** (0.0083)	-0.0202** (0.0083)	-0.0204** (0.0083)	1.4889
Fourth order polynomial Tribal2015		-0.0062 (0.0079)	-0.0090 (0.0081)	-0.0164** (0.0083)	-0.0194** (0.0084)	-0.0149* (0.0087)	-0.0198** (0.0084)	1.6673
Control Variables	Townships	√	√	√	√	√	√	
	Soil Productivity	√	√	√	√	√	√	
Observations (out/in)		(7087/2506)	(6810/2506)	(6276/2505)	(5313/2479)	(3523/2455)		

Data

- Balance check test variables:
  - **Temperature and Precipitation** raster datasets: WorldClim1.4: Current condition (~1960-1990). (resolution: 30 arc-second (~1km).)
    - Temperature: Annual mean temperature, Max temperature of warmest month, Min temperature of coldest month
    - Precipitation: Annual precipitation, Precipitation of Driest Month
  - **Elevation** raster data: NASA Shuttle Radar Topographic Mission (SRTM) 90m Digital Elevation Dataset. (resolution: 3 arc-second (~90m)).
  - **Soil productivity**: Soil productivity index grid (Schaetzl et al., 2012)